SMALL ARMS DESIGN AND BALLISTICS

WHELEN

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FRONTISPIECE

Author and J. Bushnell Smith conducting a simple ballistic experiment on the rifle range.

SMALL ARMS DESIGN AND BALLISTICS

Volume II

BALLISTICS

BY

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CONTENTS

CHAPTER		PAGE
	SMALL ARMS BALLISTICS—INTRODUCTION	vii
I.	INTERIOR BALLISTICS	1
II.	DETERMINATION OF PRESSURE AND VELOCITY	33
III.	RECOIL, JUMP, AND VIBRATION	50
IV.	EXTERIOR BALLISTICS	73
V.	TRAJECTORY—A STUDY	86
VI.	DETERMINATION OF TRAJECTORY	121
VII.	WIND DEFLECTION	130
VIII.	WOUNDING EFFECT AND KILLING POWER	136
IX.	TESTING RANGES, RESTS, AND RECORDS	157
X.	SHOTGUN BALLISTICS	187
XI.	CARE AND STORAGE OF ARMS AND AMMUNITION	213
XII.	HAND LOADING AMMUNITION	229
XIII.	OLD RECORDS, EXPERIENCES AND OPINIONS	238
	APPENDIX	275

FOREWORD

THIS is the second and final volume of Small Arms Design and Ballistics, and deals chiefly with Ballistics. Volume I covered Design.

Unless the reader is fairly familiar with the various types of small arms, their design and the reasons therefor, and the terminology thereof, it is advised that he read Volume I before proceeding with this work.

Introduction

BALLISTICS is that branch of Applied Physics which deals with the motion of projectiles and the conditions governing that motion. In practice the subject is confined to military projectiles such as small arms bullets, artillery shells, and airplane bombs. There are two principal divisions of the subject, **Interior Ballistics** which deals with the motion of the projectile while still in the gun, and **Exterior Ballistics** which deals with the motion of the projectile in free air.

Ballistics in its purely scientific aspect is a rather intricate mathematical science which not one college graduate in a thousand is capable of pursuing successfully without considerable additional study. It requires not only a thorough grounding in higher mathematics, but a knowledge of physics, chemistry, optics, and other sciences. Many large volumes have been written on the subject most of which are completely beyond the comprehension of the average layman.

In the matter of heavy ordnance (artillery) probably a complete and accurate knowledge of all propellants and projectiles under all conditions is required because of the many uses to which such heavy ordnance is put, and the various effects and results usually have to be determined by mathematical equations because their solution by trial and error would be too costly and tedious. But the problem of designing small arms and their cartridges, and a determination of their performance is very much simpler and less expensive.

In order to make the subject readily understandable and usable by the average layman we will include only those computations that can readily be made by simple arithmetic.

Indeed the difficult mathematical calculations and intricate scientific theory under which small arms ballistics has labored in the past is entirely unnecessary for a complete understanding of the subject and for all practical purposes. Problems solved by such methods are never more free from error, in fact are more liable to errors, than when the desired results are obtained in the simple manners sug-

gested herein. Such laborious mathematical calculations are therefore often a waste of time, introduce an element of doubt that is absent when the solution is arrived at in a practical manner, and for this reason have been omitted from this work. So far as small arms are concerned, ballistics is not a deep or difficult subject, but one that is simple and easily understandable by any high school graduate.

A modern small-arm, particularly a rifle, is a very wonderful and efficient instrument. With it we can hit, and kill or destroy an object at a very great distance, and with remarkable consistency, provided we understand the weapon, the flight of the projectile, and are skilled in its use. First of all a knowledge of and skill in marksmanship is necessary. There are many excellent works on the subject of Marksmanship. But in addition a knowledge of Design and Ballistics is essential for the most effective use of any weapon.

A knowledge of Design helps us to select a proper and efficient small-arm to meet our particular needs, to eliminate the poor and unsuitable designs, to familiarize us with the mechanism of the weapon, how it operates, and with what care and precautions it should be used; and what ammunition can and should be used in each particular weapon.

Ballistics makes us familiar with the flight of the projectile, without which knowledge we could not strike an object at any considerable distance no matter what our skill in marksmanship. We learn the conditions, both inside and outside the weapon, that influence the bullet—velocity, trajectory, air resistance, the drop of the bullet, maintenance of energy, penetration, killing power, wind deflection, and many other matters, all very necessary information for the soldier, sportsman, or target shooter desiring to master his weapon so as to obtain the maximum results under all conditions.

All previous works have dealt with these subjects of Design and Ballistics in a very brief, superficial, and entirely inadequate manner, or else have been so extremely scientific in their approach as to be beyond the understanding of the average user of small arms, who, above all others, needs such information. Accordingly this work has been undertaken in the hopes that it may assist the Marksmen of America to soar to greater heights, to make higher scores, to kill their game cleanly, and to defeat all enemies of Liberty and Justice.

The writer has "sat at the feet" of most of the prominent ordnance and ballistic engineers who have been prominent in the United States from 1900 to date. To all of these he is much indebted, and particularly to Major General Julian S. Hatcher, Ordnance Department, United States Army; Mr. Wallace H. Coxe, Ballistic Engineer, E. I. du Pont De Nemours & Co.; Mr. Merton A. Robinson, Ballistic Engineer, Winchester Repeating Arms Co.; and to

Mr. C. S. Cummings and Mr. W. E. Witsil, Ballistic Engineers, Remington Arms Company.

It would be strange indeed if a work of this kind did not contain some errors and omissions. It may also contain statements now believed correct, but which the future will show to be erroneous. The writer feels like a young Army Officer of his acquaintance who, undergoing examination for promotion, placed at the end of his last paper the notation; "If I have said anything for which I am sorry, I am much obliged."

TOWNSEND WHELEN

Washington, D.C.
May 1, 1945.

CHAPTER I

Interior Ballistics

IN THE study of the interior ballistics of small arms we are concerned with such details as ignition, burning of powder, pressure, velocity, twist of rifling, bullet fit, strength of parts, erosion, wear, recoil, jump, and vibration. In fact all details concerning the impulse which delivers the projectile, moving to the front, into the air. Unlike most other engines the projectile obtains its entire energy of propulsion in the gun, during the very small fraction of a second before it leaves the muzzle. There is no continuing augmentation of energy as in the case of the locomotive, automobile, or airplane.

As a preliminary we must describe the events which take place from the instant the striker or firing pin is released from the control of the sear until the projectile has departed into free air beyond the effect of the muzzle blast. We will here confine ourselves to these occurrences in a rifle or pistol. Afterwards we will consider the slightly different happenings in a shotgun. The outstanding characteristic of these occurrences is their extreme rapidity. The whole period from the release of the trigger and sear until the issuance of the projectile from the muzzle is not greater than a hundredth of a second, and may be considerably less. The whole period may be divided into three smaller periods; (1) Lock Time, (2) Ignition Time, and (3) Barrel Time.

Lock Time and Lock Energy

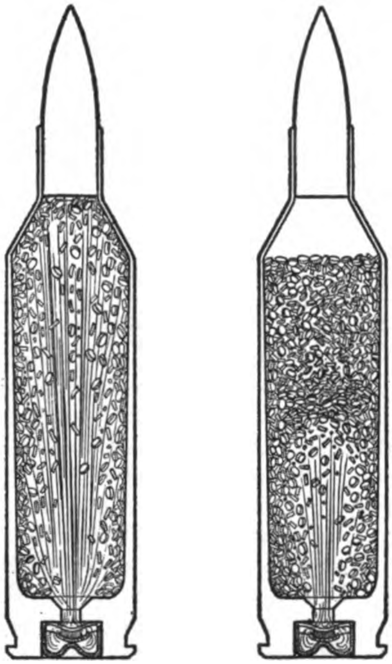
When the trigger is squeezed or pressed it depresses the sear, which releases the striker or firing pin. The striker, actuated by the mainspring, flies forward and indents the primer, thus crushing and igniting the priming mixture. As we have seen in Volume I, the time from sear release to striking of the primer depends upon the length of travel of the striker, the weight of the striker and other moving parts, and the strength of the mainspring, and is termed "lock time." In the Short Model Lee Enfield (S.M.L.E.) rifle this time is approximately .0058 second, in the Model 1903 Springfield

approximately .0057 second, while the Model 52 Winchester small bore rifle has one of the shortest of all lock times, approximating .0022 second. Lock time is of importance chiefly from the standpoint of practical marksmanship. Theoretically the marksman squeezes the trigger when his aim is correct. It is possible that the rifle may move, and the aim may thus be altered, between the instant that the trigger releases the sear, and when the striker indents the primer. A short lock time is therefore an advantage.

But from the standpoint of interior ballistics the energy of the striker blow is of more importance than its speed. The energy of course depends upon the speed and the weight of the moving parts. If the energy is not great enough the priming mixture will not be crushed properly, and a low order of ignition, a hangfire, or a misfire may occur. A low order of ignition, perhaps tending towards a hangfire, has been known to decrease the muzzle velocity as much as 100 f.s., and has a bad effect on accuracy. If the energy be too great the primer may be punctured with all the attending dangers, and the escape of gas to the rear lessens the amount and pressure of the propelling gas which gives motion to the bullet. Different types and makes of primers also require a different energy of striker blow to ignite them in an ideal manner (Volume I).

Ignition

When the priming mixture is crushed it explodes and ignites the propellant powder. This ignition, if normal, takes place in the exceedingly short time interval of about .0002-second. This is a most important phase in interior ballistics. The efficiency as well as the time of ignition depends upon the volume and the heat of the flame given off by the exploding primer composition. These must be correct for the kind, type, and granulation of the powder that is to be ignited, for the volume of the charge, for the size and shape of the powder chamber within the case, and for the diameter of the flash hole in the primer pocket. Generally speaking, the flash should have such volume and strength that it intrudes itself into all the air space between the powder grains for the full or nearly full capacity of the powder chamber within the case, thus igniting simultaneously all the grains of powder that comprise the charge. The flash should not merely ignite those grains of powder that lie at the base of the case nearest the flash hole. Black powder ignited very easily, and a relatively weak primer was sufficient for it, but smokeless powders are much more difficult to ignite. Fine grained powders, and nitroglycerin powders ignite easier and require a less powerful primer than coarse grained and nitro-cellulose powders. A cartridge having a large powder chamber requires a strong primer. A primer designed for a pistol cartridge will usually give a very low order of ignition



A B

FIGURE 1. IGNITION

A. Perfect ignition. The primer flash fills the powder space almost completely, igniting almost all of the powder grains simultaneously. Such primer flash gives uniform velocities and good accuracy.

B. A low order of ignition. The primer flash is scanty, igniting only a few grains of powder, and depending on the burning of those grains to ignite the remainder of the charge. The velocity from shot to shot varies, the accuracy is poor, and there may be an occasional hang-fire.

With the present excellent primers now produced by our leading cartridge companies one seldom sees a primer flash approaching B, except where a pistol primer has been used in a large rifle cartridge, or exposure to dampness or oil has deteriorated the primer.

and poor results in a large rifle cartridge. On the other side, strong primers in small cartridges are bad business, giving high and erratic pressures and poor accuracy.

As an example: The recent du Pont No. 4759 powder has given exceptionally fine results in medium and reduced loads in many cartridges for which it is suitable. It is very easily ignited and requires a primer of medium strength such as the Winchester No. 115. In fact, even in the large .30-06 case, it may often be ignited per-

fectly with a pistol primer. But the strong rifle primers over-ignite it and give poor accuracy and probably high and erratic pressures.

Two strengths of the large size rifle primer are at present furnished on the American market. The stronger one, typified by the Winchester No. 120, is intended for the larger rifle cartridges only, such as .270 Win., and .30-06. The moderate primers such as the Winchester No. 115 are intended for the moderate and smaller size rifle cartridges that take the large size primer, such as the .25-35 to the .35 Remington. The .250-3000 Savage cartridge seems to mark about the dividing line where the lighter and stronger primers should be used. In several instances (but not invariably) the writer, experimenting with this cartridge and full charges of du Pont powders has obtained fine results with the No. 115 primer, and very mediocre results so far as accuracy is concerned, with the No. 120.

When the priming composition is fairly crushed it explodes with what is termed a detonation. This is a most amazing phenomenon. The little pellet weighing perhaps half a grain turns into gas at very high temperature at once, probably in .00001 second, changing from a solid at air temperature to a white hot mass of gas, and generating a pressure of some 10,000 pounds in itself. But due to the cooling it gets from the cold walls of the case and the cold powder grains, the actual primer pressure within the case is probably not much over 2,000 pounds. The powder chamber is filled with intensely hot gas practically instantly when ignition is correct.

The Burning of the Powder

When the surface of the powder grains has been well ignited, the propellant powder begins to make gas, and the pressure in the powder chamber rises. The interior surface of the case and the remainder of the powder are heated. The powder burns faster and faster, and gives off more gas. The gas, now at high pressure and great heat, spurts into every crack and crevice it can find. It can, however, produce motion only at the expense of time. The powder grains burn from their outer surfaces more and more violently. The pressure rises, and from it the walls of the brass cartridge case swell outwardly more and more until they stop against the chamber walls of the steel barrel. The swelling of the sides of the case progresses or "rolls" forward until it involves the neck of the case. The neck, expanding against the chamber walls, frees its friction tight hold on the bullet which is now released to move forward. Being heavy, the bullet starts forward slowly from the rising pressure of gas on its base. In the meantime a small crevice has developed between the expanding case neck and the walls of the bullet. As the bullet has not yet advanced far enough to enter and seal the bore, this crevice between the case neck and the walls of the bullet introduces a leaky

spot. We have seen that gas at high pressure leaks into every crack and crevice that it finds. Some of it leaks into this crevice and around the bullet into the bore, and a photograph taken of the muzzle of a rifle just as the point of the bullet emerges from it shows a small puff of black powder gas emerging from the muzzle *ahead* of the bullet. See Figure 2. Some of the gas rushing through this crevice also passes around the mouth of the case and starts backward between the outer walls of the case and the walls of the chamber, but it does not get very far before the expanding case neck and shoulder shuts it off. With proper dimensions and conditions this gas should not blacken the outside of the neck of the case further than about one-fourth inch back from the mouth.

The bullet moving forward now enters the bullet seat and the leade, and is forced up into the rifling. If the bullet is a close enough fit (large enough) with respect to the bore and rifling, or if it be soft enough to expand from gas pressure on its base, it now seals the bore, and all further movement of gas is confined behind the bullet.

In the meantime more and more of the powder grains are burning, giving off more gas, and the gas pressure continues to rise very rapidly. The gas usually reaches its peak of pressure when the bullet has completely entered the bore, or in some cases not until the bullet has passed two to five inches down the bore, depending on the rate of burning of the powder, on the fit of the bullet in the bore, on the weight and hardness of the bullet, and on the length of bearing (friction) of the bullet in the bore. Pressure rises quicker with fine grained and nitroglycerin powders than with coarse and tubular grained and nitro-cellulose powders, and slower with progressive burning than with regular burning powders. Tight, hard, heavy, and long bullets require more force and time to drive them into the rifling and cause pressures to rise faster and higher. The force required to enter a bullet through bullet seat and leade into the rifling is termed "*forcement*" and is a very important factor in the rate of rise of pressure and in the amount of chamber pressure. Ballisticians find it difficult to compute forcement, and this is one of the unknown factors that cause a disagreement between calculated and measured pressures.

As the bullet proceeds up the bore the size of the chamber or space within which the powder is burning is continually increasing. At first the gases were confined entirely to the powder chamber within the case. The pressure was then not at its peak because the powder grains were not then burning at their peak of gas generation. Now, as the bullet proceeds forward, the powder chamber is being rapidly increased by the amount of bore behind the bullet into which the gas can expand. Then as the bullet moves forward faster and faster the powder chamber capacity increases so quickly

that it wins the race over the gas, and the pressure begins to drop. But there is still enough pressure clear to the muzzle to continue hard pressure against the base of the bullet, and continually increase its forward velocity. See Figure 3.

In the case of the normal .30-06, M2 service cartridge, loaded with 150 grain bullet and du Pont IMR No. 4064 powder, M.V. 2800 f.s., the breech pressure is about 42,000 pounds, while a pressure gauge located close to the muzzle shows a pressure there of about 8,000 pounds. This for a 24 inch barrel. However, were the barrel to be only 20 inches long instead of 24 inches then the muzzle velocity would be reduced about 100 f.s. because the gas, even though it had only 10,000 to 8,000 pounds pressure near the muzzle would have pressed on the bullet for that much less time. Conversely if we increase the barrel length the muzzle velocity will increase approximately 25 f.s. for each inch of increased length up to about 32 inches, by which time the powder grains have all been consumed, no more gas is being generated, and the pressure on the base of the bullet has fallen too low to augment the velocity.

With other cartridges the increase or decrease in velocity caused by increasing or decreasing the barrel length may be greater or smaller per inch, according to the volume and generation of gas. With .22 rim fire cartridges the highest velocity is obtained with a barrel 16 to 20 inches long, all the powder having burned in that length. Some rifles for the .22 Long Rifle cartridge are made with barrels 28 inches long, and with these the muzzle velocity is actually a little less than it would have been had the barrel been only 20 inches long, the added eight inches only serving to increase the friction.

Our old .30-40 Krag Jorgensen rifle (U.S. Magazine Rifle, Caliber .30, Model 1898) had a 30 inch barrel, and the muzzle velocity was 2000 f.s. The carbine had a 22 inch barrel, and its muzzle velocity was 1920 f.s. This with the service cartridge, 35 grains of W.A. powder and a 220 grain full jacketed bullet. W.A. was a nitroglycerin powder.

The .30-06 Springfield rifle (U.S. Rifle, Cal. .30, Model 1903) in a test for velocity, starting with a 32 inch barrel and cutting it off two inches at a time gave: 32 inches, 2848 f.s.; 30 inches—2833 f.s.; 28 inches—2776 f.s.; 26 inches—2743 f.s.; 24 inches—2709 f.s. This with the Ball Cartridge Model 1906, 150 grain bullet and Pyro D.G. powder.

With present powders the practice with rifles is to evaluate the difference made by one inch of barrel length between total lengths of from 20 to 30 inches as follows: For velocities around 4000 f.s., 40 feet; 3000 f.s.—30 feet; 2700 f.s.—25 feet; 2400 f.s.—20 feet; 2000 f.s.—15 feet, 1500 f.s.—15 feet.

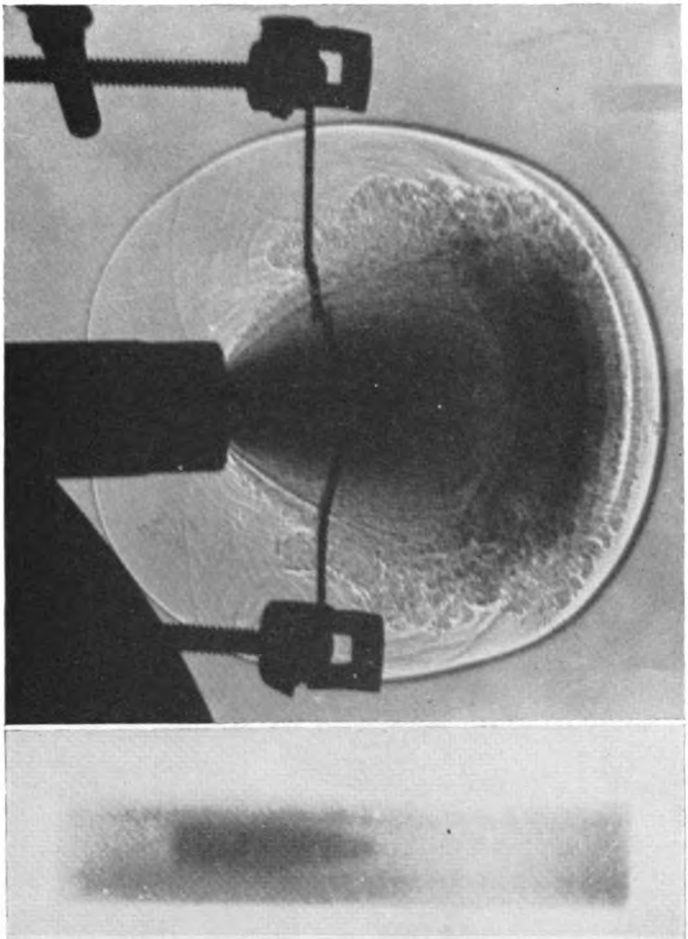


FIGURE 2

A spark shadowgraph showing the powder blast and smoke emerging from the muzzle of a Caliber .30 rifle ahead of the bullet. This is the blast and smoke from the gas that by-passes the bullet as the latter jumps from the case through the bullet seat and leade, and before the base of the bullet has sealed the bore. It is this escaping powder gas that is largely responsible for much of the erosion in rifle barrels.

The wire, the breaking of which by the blast, cuts the electric circuit and takes the photograph, consists of a lead refill for an Eversharp pencil. The circular line is the sound wave travelling outward from the muzzle at a velocity of approximately 1100 f.s.

The smaller photograph is a high speed X-ray picture, also taken simultaneously with the larger, and shows the bullet several inches inside the bore of the rifle when the powder gas emerged from the muzzle.

Photographs by E. R. Thilo, Ordnance Laboratory, Frankford Arsenal

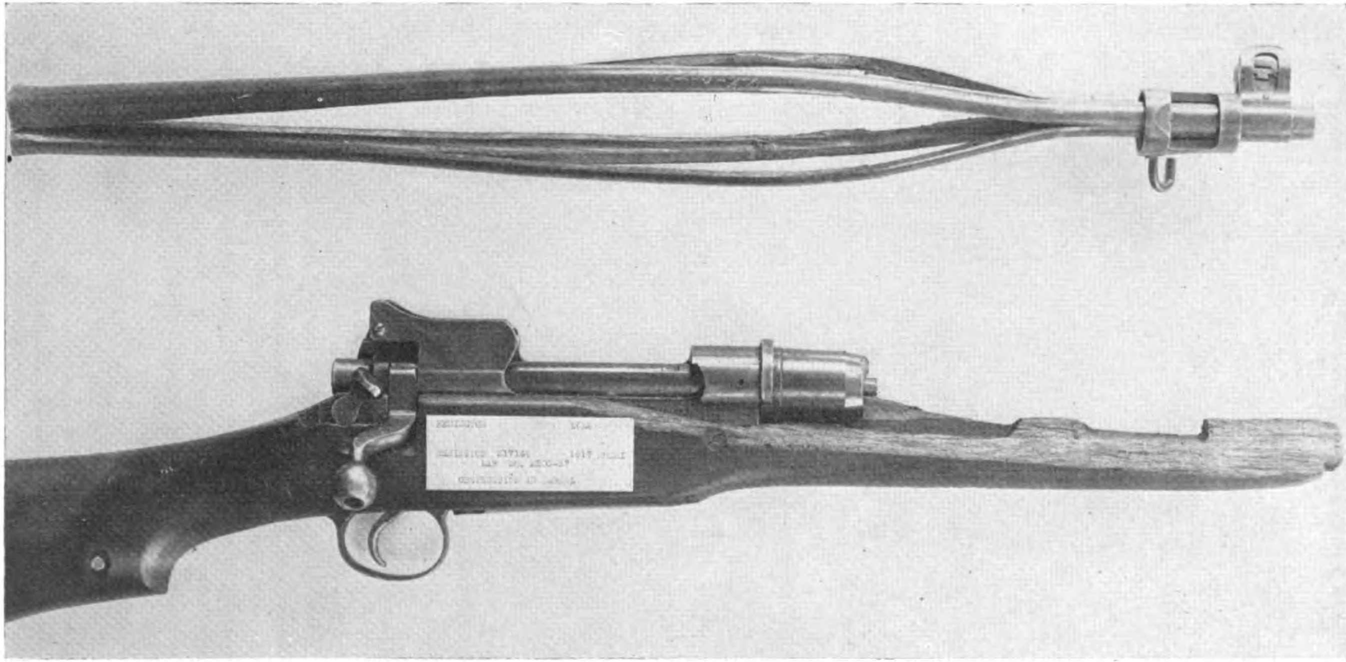


FIGURE 4A. EXCESSIVE PRESSURE

The result of firing a normal service cartridge in a U.S. Rifle, Model 1917 (Enfield) with the bore more or less thickly coated with heavy grease. Service rifles, and many commercial rifles, are shipped from the manufacturer with the bore heavily greased to prevent corrosion, and this grease *must* always be removed before firing. Bore obstructions, unless they are immediately in front of the chamber, always result in a burst, split, or bulged barrel.

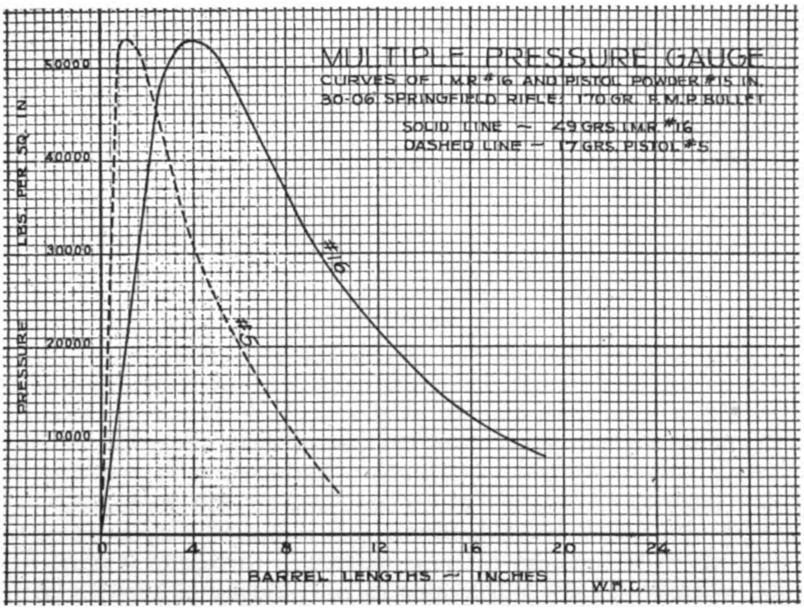


FIGURE 3. HOW SMOKELESS POWDER BURNS

Pressure curves as determined with a number of pressure gauges located at points from breech to muzzle in the barrel of a .30-06 Springfield rifle.

Note how the pressure rises very quickly to its peak of about 52,000 pounds when the bullet has travelled about 4 inches from the breech, and how it then gradually falls off, as the bullet travels up the bore and enlarges the burning chamber, until it is only about 6,000 pounds at the muzzle. The solid line shows the well sustained pressure of du Pont I.M.R. No. 16 Powder, one of the early progressive burning powders. This pressure gives a velocity of about 2800 f.s.

The dashed curve shows what happens when we use a very quick burning powder such as du Pont Pistol Powder No. 5 in a rifle. The load of 17 grains gives a breech pressure just as high as 49 grains of No. 16, but the rise in pressure is very quick, the peak coming when the bullet has advanced only about 1½ inches. Then the pressure falls off very fast so that all the powder has burned by the time the bullet has advanced only about 10½ inches up the bore. From then on there is no continuing pressure on the base of the bullet and no augmentation of velocity. The last thirteen inches of bore simply acts to delay the bullet by friction. Despite the breech pressure of 52,000 pounds, the muzzle velocity is probably not over 1200 f.s. Such powder is properly used only in pistols, where it all burns in the short barrels of such weapons.

With revolvers and pistols for the .22 Long Rifle regular velocity cartridge, which in an 18 inch barrel gives M.V. about 1050 to 1100 f.s., the velocities will run: 4 inch barrel about 750 to 800 f.s.; 6 inches about 850 to 875 f.s., 8 inches about 925 to 975 f.s.; 10 inches about 950 to 1000 f.s. With revolvers and pistols using cartridges of

larger bore, almost all such cartridges are loaded with a very quick burning powder which is consumed in a very short length of barrel, and increased barrel length does not add much to velocity. Indeed there are cases where an 8½ inch barrel gave a lower velocity than one 6 inches long.

Unless the gas pressure has fallen to a very low figure by the time the bullet has reached the muzzle, there is a small increase in velocity for a few inches beyond the muzzle, caused by the muzzle blast continuing to press against the base of the bullet. It is probably not more than a few foot seconds.

Barrel Time

Like the movement of the striker and lock, and the ignition of the charge, the travel of the bullet up the bore is taking time, although a very small amount of time indeed. This time, from the detonation of the primer and ignition of the powder to the departure of the bullet from the muzzle is termed the "barrel time." It may be assumed that if a bullet has a muzzle velocity of 2800 f.s. it is travelling then at a rate of one foot in $1/2800$ of a second or two feet (the barrel length) in $1/1400$ second. In the barrel it starts from the chamber at rest and attains its full velocity of 2800 f.s. at the muzzle. Therefore its barrel time should be one half of $1/1400$ f.s. or $1/700$ f.s., or expressed in decimals .0014 second.

This, however, is not quite correct because the pressure is much higher towards the breech of the barrel, and there is a steady augmentation of velocity to the muzzle. Thus the bullet increases in velocity faster in the breech half than in the muzzle half of the barrel, and the curve of the velocity if plotted out resembles a parabola where the average value of all the velocities is two thirds the final velocity. Thus the average speed would be two thirds of 2800 f.s. or 1867 f.s., and the time required to travel 24 inches at this speed would be $1/933$ second, or expressed in decimals .00107 second, or about a thousandth of a second.

Similarly Hatcher has calculated the barrel time of the .45 Colt Auto cartridge, M.V. 810 f.s., fired in the 5 inch barrel of the .45 Colt Automatic Pistol, to be .00077 second. Here, despite the low velocity of the bullet, the barrel time is short because of the very short barrel.

Thus we may say that the time for all the happenings in interior ballistics from the release of the sear until the issue of the bullet from the muzzle is approximately;

Lock time	.0022	to	.0057	second.
Ignition time	.0002		.0002	
Barrel time	.00077		.00107	
Total time	.00317	to	.00697	second.

The above gives a mental picture of what occurs in a rifle or pistol from the time the trigger is pressed until the bullet leaves the muzzle. But there are certain of these happenings which we should consider in greater detail.

Pressure

The first rule in designing a cartridge for a given weapon and in establishing a charge for that cartridge, is that the pressure must not exceed the safe working pressure that the weapon is capable of withstanding. And conversely in designing a weapon for a certain cartridge the design and materials must be such as to satisfactorily withstand the normal pressure of that cartridge, and incidentally to withstand a proof charge that is one fourth greater in pressure than the normal.

As we have already seen there are many factors that determine the pressure, such as the kind and amount of the powder charge, the density of the loading, the weight, material, size, and length of the bullet, the diameter of bore and twist of rifling, the type of bullet seat and leade, etc. The influence of some of these factors has already been discussed in Volume I; others will be considered as we proceed. We have also seen in Volume I that the brass cartridge case is ordinarily the weakest link in withstanding pressure, and that the design and anneal of the case must be given serious consideration.

A word or two of caution should be injected here, because excessive pressure is such a dangerous condition. Let us say that the established normal pressure for a certain rifle cartridge is 48,000 pounds per square inch. But a certain experimenter figures that as he is using a rifle reputed to be very strong he can safely load this cartridge to a mean pressure of 52,000 pounds. In proper practice, pressures are determined at a temperature of 70 degrees F. Perhaps he can safely load to this pressure if everything else remains normal. But he may be using a mechanical powder measure, or he makes a small error in weighing his charge, and it happens, as it often will, that in one cartridge he gets a half grain more powder than he intended. When loading close to the maximum charge, or just a trifle over it, a half grain more of powder will increase the pressure far more than might be expected. Suppose in this case it increases the pressure to 60,000 pounds—the case may or may not hold this pressure. Possibly it will, but it may swell or stick in the chamber a little, or the primer may leak. But furthermore suppose this experimenter is using this cartridge on the rifle range on a sunny day of summer when the air temperature is in the nineties, and he lets his cartridges lie exposed on the firing line to the direct heat of the sun for some time. Under such conditions the cartridge with half a grain over-

charge can easily give 75,000 pounds pressure, the brass case will almost certainly give way, the breech mechanism of the rifle may be more or less demolished, and the experimenter may be seriously injured. A number of accidents have been traced to causes almost identical with this. There are many other factors and combinations thereof which will result in excessive pressures, and it is up to the ballistician, the designer, and the experimenter to become familiar with these details and to observe the rules for safe design and loading. Such rules are explained in detail throughout the two volumes of this work.

The Combustion Chamber. In black powder days almost all powder chambers were straight cylinders, approximately the diameter of the bore, and as long as necessary to contain the amount of powder desired. That is, the cartridge case was practically straight, almost exactly a straight cylinder in the powder chamber, and only enough taper outside to insure fairly easy extraction. Such cases varied from the extremely short pistol cartridges such as the .32 and .38 Short, to the extremely long cases of the .40-90-370 and .45-125-550 Sharps. These latter very long cartridges required a heavy bullet to develop sufficient pressure to cause the long column of black powder to burn and to be fairly completely consumed within the barrel length, and a barrel about 30 inches long was required. Conversely the short cases were loaded with light bullets for use in hand guns, the bullet was firmly crimped in the case, and a finely grained black powder was used so that it would burn fast enough and set up the required pressure within the combustion chamber to burn completely and give the desired velocity within the short barrel of the pistol.

Black powder is quite instantaneous in its burning. Light a small pile of it in the open and it goes off instantly, with a big puff of smoke. On the contrary all smokeless powders are much slower burning. A pile lit in the open burns slowly, taking several seconds to be consumed, but the more pressure one places on smokeless powder the faster it burns.

With early smokeless powders attempt was naturally made to adapt them to the older black powder cartridges, but the results were rather mediocre because it was difficult to make the powder burn fast enough and with uniform pressure. This difficulty has since been overcome by the development of faster burning smokeless powders for use in pistol and older rifle cartridges.

The difficulties of adopting smokeless powders to straight cases soon led to the bottle necked case, which has more capacity in proportion to its length than the older straight cases, and thus permits a larger charge of powder within a case that is not prohibitively long for the breech action. A larger charge of powder, of course,

means more velocity up to the limit of safe pressure with the particular powder. The shoulder of this bottle necked case and its relatively small bullet vent acted to retain more of the gases within the combustion chamber, and to "churn" them up more, and this caused higher pressure and more complete burning.

The history of the bottle necked case shows that ballisticians were always a little fearful of the pressures developed by it. There was a certain effort to get away from it by making the slope of the shoulder less acute. But more recent developments seem to indicate that, with present day powders, the abrupt slope of the neck is an advantage rather than otherwise, and that in many existing designs this slope can be increased with positive advantage.

The abrupt shoulder tends to deflect the gases back on themselves, assuring faster and more complete burning of the powder. Apparently the pressure, although high, is more uniform, resulting in a flatter trajectory and better accuracy. A larger proportion of the powder is consumed within the case, and not so much of it appears to burn in and on the bullet seat, leade, and bore. As a consequence erosion proceeds more slowly and the accuracy life of the barrel is prolonged. Examples of the abrupt shoulder are seen in the .250-3000 Savage, .22 Kilbourn Hornet, .22-3000 Lovell 2R, and .22 Varminter cartridges. This development is comparatively new and has not yet been fully investigated, but it is believed that the abrupt shoulder is of more advantage in small than in large calibers.

A small arm is a relatively inefficient form of gas engine. Ordinarily it utilizes only about forty to sixty percent of the gas generated in the useful work of propelling the projectile. The remainder is dissipated in developing heat, overcoming friction, expanding the case, in recoil, gas escape, and otherwise. But the case with the abrupt shoulder seems to increase the proportionate effectiveness of the rifle. Compare, for example, the .22-3000 Lovell 2-R cartridge having a sharp shoulder, with the .22 Savage High Power cartridge with gently sloping shoulder. The former with only 15.5 to 17 grains of powder develops M.V. 3000 to 3150, f.s. with a 50 to 55 grain bullet. The latter, with a much larger charge of powder, 21 grains, develops only M.V. 2780 f.s. with a 70 grain bullet. Even if we used a 50 grain bullet in the Savage case it would probably take 25 grains of powder (No. 4198) to develop the same velocity that we can get with 17 grains in the 2-R.

Increasing the powder capacity of the case obviously permits a larger charge of powder to be loaded, but may require an entirely different powder to be used. Compare, for example, the powder capacity of the .25-20; .25-35 W.C.F.; .250-3000 Savage, and .257 Roberts cartridges. The capacity of the first is quite small, that of the latter large, yet all of these cartridges are of the same caliber and

use the same diameter of bullet. Now, in rifles of the same bore diameter, if we use a large capacity case and a large powder charge we must give the combustion chamber a longer time to empty itself than if we used a small case and small charge, or we will run the pressure up dangerously high. There is only one way we can do this; use a powder in the larger case that burns more slowly than the powder we used in the smaller case. A very suitable powder for the small .25-20 case is du Pont No. 4227 * which is a fine grained, fast burning powder. The proper charge fills the powder space in the cartridge fairly full. If we were to fill the .25-35 case fairly full of this powder, with the same density of loading, a very high pressure would result. It is true that we could load the .25-35 case only half full of 4227 powder and thus reduce the pressure to a safe figure, but this would also reduce the velocity close to that of the .25-20, and there would be no point in using the larger and more expensive case. The proper powders for the .25-35 cartridge are du Pont Nos. 4198 or 3031. No. 4198 burns slower than 4227, and faster than 3031. We shall have to use a slightly smaller charge of 4198 than of 3031 because the former burns faster, but either powder will give satisfactory results with considerably higher muzzle velocity than we could obtain from the .25-20 cartridge. No. 4198 is more suitable for a light bullet like one of 87 grains, because the light bullet offers less bore resistance and friction and pressures do not rise so fast. No. 3031 is better adapted to heavier bullets of 100 and 117 grains weight. It is interesting to compare the tables of safe and suitable charges of these powders for these two cartridges:

.25-20 Repeater	60	gr.	bullet,	9.7	grs	4227	M.V.	1785 f.s.
	60	"	"	12.7	"	4227		2195
	86	"	"	8.7	"	4227		1410
	86	"	"	10.7	"	4227		1745
.25-35 W.C.F.	87	"	"	19.0	"	4198		2260
	87	"	"	21.5	"	4198		2560
	100	"	"	18.0	"	4198		2110
	100	"	"	21.0	"	4198		2365
	117	"	"	17.5	"	4198		1930
	117	"	"	20.5	"	4198		2210
	87	"	"	25.0	"	3031		2310
	87	"	"	30.0	"	3031		2795
	100	"	"	23.0	"	3031		2060
	100	"	"	27.0	"	3031		2450
	117	"	"	21.0	"	3031		1930
	117	"	"	26.5	"	3031		2350

* These cartridges and powders are completely described in Volume I.

Two charges for each weight of bullet are given above. The lighter is the smallest charge that will give sufficient pressure to burn the powder cleanly and fairly completely. The larger charge approaches the maximum pressure that is safe in the rifle and case, and should never be exceeded. It will be noticed that in the .25-35 we can obtain much greater velocity with all bullets with No. 3031 powder than with No. 4198. Nevertheless with the 87 grain bullet we would expect a little better accuracy from the use of No. 4198 because it burns at a pressure a little more suitable for the light bullet.

The reason why we can use heavier bullets in the .25-35 than in the .25-20 cartridge is because the barrel of the former caliber rifle has a twist of rifling of one turn in 8½ inches, and that twist will stabilize the long 117 grain bullet even when it is fired at as low a muzzle velocity as 1930 f.s. The .25-20 barrels, on the other hand, are cut with a 16 inch twist; such a twist would not stabilize even a 100 grain bullet unless the velocity were at least 2000 f.s., and such a velocity cannot be obtained with that bullet in the small capacity .25-20 case with permissible pressures.

Let us now look at the .250-3000 Savage cartridge. It has a very much larger powder capacity than the .25-35. No. 4198 powder cannot be used in it except in rather reduced loads which would give rather low velocity. More suitable powders are No. 3031 or the slightly slower burning No. 4320, the latter being better for the heaviest bullets. The following safe charges have been developed for use in modern bolt action rifles:

87	gr.	bullet.	29.0	grs	3031	M.V. 2600 f.s.
87	"	"	36.5	"	3031	3110
100	"	"	28.0	"	3031	2420
100	"	"	34.0	"	3031	2830
87	"	"	32.0	"	4320	2535
87	"	"	38.0	"	4320	3030
100	"	"	30.0	"	4320	2425
100	"	"	36.0	"	4320	2820

Because No. 4320 powder burns slower than 3031 we have to use a slightly heavier charge of it to obtain an equal velocity, but either powder is suitable, the pressure and burning of 4320 being perhaps more suitable for fine accuracy with the 100 grain bullet than is 3031.

The above .250-3000 Savage charges were developed for use in strong bolt action rifles. This cartridge is also adapted to the Savage Model 1899 lever action rifle, but this action is not quite so strong, and the maximum charges above must be reduced at least a grain in weight for use in the lever action.

The reason why the 117 grain bullet is not listed for the .250-3000 Savage cartridge is because the barrel has a twist of rifling of one turn in 14 inches, being designed primarily to stabilize the 87 grain bullet. This twist will also stabilize the 100 grain bullet satisfactorily at M.V. 2400 f.s., and possibly at lower velocities, but it would not stabilize the 117 grain bullet, and such bullets would not rotate fast enough for their length and would keyhole unless in the 14 inch twist a velocity of at least 2600 f.s. were given to them; such a velocity with the 117 grain bullet is not possible with this cartridge as the powder charge to give it would give excessive pressure.

In late years the Winchester Repeating Arms Company has been rifling their .250-3000 barrels for their Model 70 bolt action rifle (a very strong action) with a twist of one turn in 12 inches. In this twist a muzzle velocity of 2500 f.s. will stabilize the 117 grain bullet, and this bullet can be given this velocity with safety in this strong rifle by using a maximum charge of No. 4320 powder, or the much slower burning No. 4350 powder.

The .257 Roberts cartridge has a powder capacity slightly greater than the .250-3000 Savage cartridge and the twist is 10 inches. Therefore, slightly larger powder charges can be used to give 50 to 100 f.s. more velocity with bullets of equal weight than can be obtained in the Savage cartridge. Also the 117 grain bullet is easily stabilized in this twist, and can be given a muzzle velocity of 2700 f.s. with permissible pressures. The 10 inch twist, however, is a little fast for the finest accuracy with the 87 grain bullet, and usually better accuracy with this light bullet can be had in the Savage cartridge.

Similar tables of powder charges for all common calibers of American rifle cartridges and for different weights of bullets will be found in the Ideal and Belding & Mull handbooks. A study of these tables will show that the above principles pertain with all other cartridges, according to the capacity of the case and the caliber and weight of bullet used. Compare, for example, the tables for the .30-30, .30-40 Krag, .300 Savage, .30-06 U.S., and .300 H & H Magnum cartridges, all of the same caliber, but differing greatly in powder capacity.

The powder charges in these tables have been developed when using standard cases and primers, and with bullets of standard diameters and construction in barrels of standard dimensions as made by our leading arms and ammunition companies. The use of other components, or of non-standard barrels must be approached with great caution. For example, if the bullet is only a thousandth inch larger in diameter, or has a longer bearing surface, or is made of harder materials than standard it may give greater bore resistance and friction, and raise pressure to a dangerous extent unless the powder charge is reduced. Before the war most excellent bullets were made

by the Western Tool and Copper Works, but almost all of them were of harder construction and had thicker jackets than standard factory bullets, and when they were used the maximum charges given in the tables had to be reduced about one grain. The writer has also seen custom built rifle barrels which had a groove diameter as much as .0015 inch smaller than standard barrels; and the shooter had best check such rifles before experimenting with them.

In these tables it is possible to interpolate between two charges to obtain the exact velocity desired. With a certain cartridge and bullet, if a 45 grain charge of a certain powder gives 2600 f.s., and a 50 grain charge gives 2800 f.s., then a charge of 47.5 grains will give very close to 2700 f.s. velocity. *But such interpolation must never be extended above the highest charge given.* Greatly increased pressures result from exceeding the maximum charge given, way out of proportion to changes of charge below the maximum. An increase of only half a grain above the maximum charge sometimes causes a rise in pressure of 5,000 to 10,000 pounds.

However, if the experimenter will make himself familiar with the various powders and tables of charges, and use common sense he can experiment and hand load his ammunition for a lifetime without any danger whatever. The writer has been hand loading and developing various loads for forty-seven years, and only once did he even approach an accident when he made an error of five grains in setting the graduations on his powder scale, fortunately without disastrous results. All such details should be checked and rechecked throughout the work.

Density of Loading. Intimately connected with the powder capacity of the case is the density of loading. If a cartridge case will hold just fifty grains of powder when filled to the base of the seated bullet, then such a charge has a density of 100 percent. Twenty five grains in this case would then give a density of loading of 50 percent.

Strictly speaking, a high density of loading is desirable because it makes for a more compact cartridge, and because the powder, if its nature permits of such loading without undue pressure, burns at better efficiency. Also the powder will be easier to ignite, and ignition and velocity are consequently more uniform. But is it not always that we can load a modern cartridge to 100 percent density, because such a large charge might give excessive pressure in that cartridge. The slower burning and coarse grained powders can usually be loaded to a higher density than can those of fine grain or quick burning. The correct charges of powder in the common high power rifle cartridges usually result in a density of 75 to 90 percent, but many of the correct charges of quick burning pistol powders in revolver and pistol cartridges give a density of under 50 percent.

With a given powder charge, different makes of the same caliber of case may give different densities because of variation in wall thickness and web of the cases. The seating depth of the bullet also affects the density. The practice of seating a bullet projecting a greater distance than normal out of the case, so that the ogive of the bullet will contact the leade, decreases the density and reduces both pressure and velocity; or conversely permits one to use a slightly increased charge of powder and get a slightly higher velocity without exceeding the pressure limit.

The ignition, and hence the accuracy, is affected by the density of loading, particularly when the density is very low. With a high density the powder grains will lie close together, and be held close to the flash hole at the base of the case. The primer flash will penetrate through the core of the powder and give maximum ignition. But with a low density, particularly if the case is less than half full, the grains lie loosely in that portion of the chamber that is lowest. If the rifle be carried with the muzzle down, and then be raised to the horizontal before firing, the charge will lie mainly at the bullet end of the case, and the primer flash will have to travel almost the length of the chamber before it reaches the powder grains. Conversely, if the powder happens to be settled close to the base of the case it will ignite well. The first condition may give a tendency to a slow ignition (hang-fire), and the two conditions occurring in a series of shots will result in uneven velocity and poor accuracy. However, poor ignition is not liable to occur in pistol and revolver cartridges, even although the density of loading is very low, because the fine grained, quick burning powder is very easy to ignite, and the case capacity is so small that the primer flash almost completely fills the combustion chamber.

With low density of loading, and consequently considerable air space in the chamber, there is a large area where heat is lost as the powder burns, and pressure and temperature are lower. With high density, the loss of heat is reduced and we get greater efficiency from our powder. By means of mathematical equations it is possible to compute chamber pressure, but with small arms such computations are never very accurate because of the difficulty of computing accurately the amount of heat released and absorbed, and the forcement—that is the force required to drive the bullet from the case through the bullet seat and leade into the bore. Therefore in practice the small arms ballistician depends largely upon actual tests with pressure gauge and chronograph to determine pressure and velocity and their relationship, rather than on calculations based on theory. The methods of measuring pressure and velocity will be discussed in the next chapter.

Powder Fouling. Intimately connected with the combustion of

the powder and the density of loading is the matter of the fouling deposited and remaining in the bore—the solid residue from the burning of the powder, the ashes as it were.

The fouling remaining in the bore was quite serious in the case of black powder used in rifles and pistols. After discharge a very considerable amount of this fouling remained in the bore, and except on extremely damp days or in the presence of an excessive amount of lubricant, it was soon "ironed" to the bore by the passage of the bullets over it and formed a hard "cake" that acted as a partial obstruction to the bore. In some cases, when looking through the bore, this cake appeared to reduce the bore to nearly half its original diameter. In many instances it accumulated so quickly and to such an extent as to seriously interfere with the accuracy of the rifle by the time ten rounds had been fired. It was always greater when the charge did not completely fill the combustion chamber of the case, so we see most black powder cartridges designed so that the proper charge was compressed by the seating of the bullet. This fouling was one of the most serious drawbacks when using black powder. It was less serious when using the Metford form of rifling and the British Curtis and Harvey black powder, than with the Enfield (American) rifling and American black powder. The cake could best be removed from the bore by swabbing with patches wet with warm water, although at times it turned out to be a matter of hard scrubbing with a bristle brush.

As explained in Volume I, the best results with black powder were obtained by cleaning the bore after each shot, or by the Pope muzzle loading system where each bullet wiped the previous fouling from the bore as it was loaded.

With all smokeless powders the amount of fouling left in the bore is very much less than with black powder, and it does not cake to nearly the same extent. The writer thinks that most smokeless powders do not leave enough fouling in the bore to have an appreciable effect on the uniformity of velocity given by the charge, but it certainly does affect the accuracy of shooting by causing more or less deformation of the bullet as it passes through the bore. A lead bullet is naturally deformed more than a jacketed bullet, and this is one of the reasons why jacketed bullets usually give better accuracy than lead bullets. In most cases lead bullets give exceedingly poor accuracy when fired through bores containing the fouling of high power cartridges.

The amount of fouling remaining in the bore after firing a certain kind of charge of powder could probably be determined accurately by chemical analysis, but the roughly proportionate amount deposited by different powders can also be distinguished by looking through the bore in a good light. Also the character of the fouling

can be told when cleaning the bore by anyone who has had long experience in cleaning,—that is whether it is easy to remove, or tenacious and sticky.

As the amount of fouling, and its tenaciousness by ironing on the bore have decreased as a result of the gradual improvement of propellant powders, so has accuracy increased, and almost in direct proportion. It is not contended that the decrease in fouling alone is responsible for all the improvement in accuracy, but it has an important bearing on it. Before about 1920 the smokeless powder used in most American high power rifles left a fouling that looked brown or dirty yellow in color, and many unburnt or partially burned grains of powder could be seen in the bore and action. This fouling was rather "sticky," and to remove it easily and quickly we used a brass wire bristle brush dipped in powder solvent. At this time the Hercules powders known as Hi-Vel and Sharpshooter gave less fouling than any of the others, and usually the best accuracy was obtained with these powders. At this period our best long range rifles were barely capable of placing ten consecutive shots in the standard bullseye (36 inches) at 1,000 yards, and our best sporting rifles gave four or five inch groups at 200 yards.

About 1922 a series of powders appeared that had tin incorporated in the grains. The tin was included in an effort to reduce the metal fouling. With these powders more fouling appeared to accumulate in the bore than with the previous powders, and it was more tenacious and extremely difficult to remove. For expeditious cleaning a brass brush dipped in powder solvent was almost absolutely necessary. The accuracy was certainly not improved over that obtained with the older powders. In fact, the writer's experience was that it was not so good.

Then about 1933 the new and present series of du Pont Improved Military Powders were introduced—those with the serial numbers from 3031 to 4350. These gave very much less fouling than any preceding powders. The fouling was not at all tenacious and was easily removed by mere swabbing with a flannel patch saturated with powder solvent or oil. A very great improvement in accuracy resulted at once. With long range rifles it was not only possible to keep all the shots in the bullseye at 1,000 yards, but a majority would strike in the V-ring close to the center. With the best sporting rifles two and three inch groups at 200 yards became quite common.

About 1940 the du Pont Company introduced their Sporting Rifle Powder No. 4759. This powder is designed for relatively moderate or low velocities in rifles with either jacketed or lead bullets. It leaves less fouling in the bore than any other powder the writer has used. Indeed, if one does not look sharply he might think that the rifle had not been fired. In all rifles in which he has tried it it

gives much better accuracy with lead bullets than any other powder. Lead bullets are extremely sensitive to any "stickiness" in the fouling. In the .22 Varminter cartridge with moderate loads and jacketed bullets, the accuracy is fully equal to that obtained with any powder at any velocity.

In Volume I the writer stated that he thought the great improvement in accuracy in small arms during the past twenty years could be attributed chiefly to the improvement in propellant powders, and it does seem as though the improvement was in direct relation to the decrease of fouling deposited in the bore. Of course this is not the only improvement in powders, but it is a material one.

Recoil, Jump, and Vibration

Gas pressure is exerted in all directions within the combustion chamber. The pressure on the base of the bullet moves it forward through the bore, the side pressure expands the case tight against the chamber walls, and the pressure on the base of the cartridge case, translated to the face of the breech, moves the whole gun backward. The pressure acts just as strongly to push the gun backward as to push the bullet forward, and it operates on the gun for just the same length of time it does on the bullet, that is until the bullet leaves the muzzle. The bullet being much lighter than the gun moves much faster and through a greater space in this time. The movement of both is in direct proportion to their weight when the gun is free to move backward, although when the shoulder is pressed against the butt of the gun that pressure must be added to the weight of the gun.

When the gun is fired from the shoulder, or when a hand gun is fired from the hand, the pressure and resistance on the butt or grip is exerted below the line of the axis of the bore, the gun in going backward tends to rotate around this point of resistance, and as a consequence it not only moves backward but upward. The portion of these movements backward and upward that takes place before the bullet leaves the muzzle is termed the "jump."

The recoil or backward movement that takes place while the bullet is still in the barrel is relatively small. There is then a still further recoil as the powder gases rush out the bore and react against the atmosphere, with a consequent reaction of the gun. These two portions of the entire recoil occur so close together that the shooter's shoulder cannot distinguish between them. The latter part of recoil does not properly belong within the realm of interior ballistics because it takes place after the bullet has departed, but it is considered so in this work because of its effect on the shooter.

When the striker is released and strikes the primer a sharp blow it sets up certain small vibrations in the gun. These vibrations are

blotted out by the much more powerful movement of jump. The extremely powerful blow of the discharge which causes the jump also sets up further vibrations which combine with the jump and may impart to the rifle a movement that is slightly different from the jump alone.

Recoil, jump, and vibration have considerable effect on the sighting of the gun, and they also have a decided bearing on the precautions that must be taken to shoot the weapon with accuracy. They will be considered in detail in a subsequent chapter.

Erosion

The gases generated by almost all smokeless powders are extremely hot, hot enough to easily melt any barrel steel if allowed to play on it continuously for a few minutes. But of course at each shot they are in contact with the steel for only about a thousandth of a second. Nevertheless they do very gradually erode, melt, and wash away the steel surface. The gases also rush over the steel at extremely high velocity when they leak over and around the bullet, as the latter passes from the case neck through the bullet seat and leade into the bore, they have considerable cutting effect on the breech of the bore just in front of the chamber. This is termed "erosion." When the bore is properly cared for so as to prevent corrosion, the barrel slowly becomes less and less accurate from the effect of this erosion until it becomes unreliable in its shooting, and then we say that the barrel is worn out.

Anything in the charge that increases temperature increases the rate of progress of the erosion. Nitroglycerin powders produce hotter gases than nitro-cellulose powders, and erosion progresses faster and is closer to the bullet seat. The moderants used in many nitro-cellulose powders tend to cooler burning and reduce the rate of erosion. The surface layers of these progressive nitro-cellulose propellants burn more slowly than the interior portions of the grains, and the heat developed just in front of the chamber is correspondingly reduced, but the erosion further forward in the bore is increased. Erosion is further increased by large powder charges, high velocity, loose bullet fit, and rifles of small bore. It progresses much faster in rapid fire than in slow fire, because the barrel steel is raised to a higher temperature.

Erosion also proceeds about twenty percent faster when boat tailed bullets are used. The boat tail, together with the slope of the inside of the case, forms a funnel which directs the gas flow in between the bullet and the bore more effectively than when the bullet has a flat base, and the bullet with its tapered base is not expanded so quickly as a flat base, and thus a gas dam in the bore is not formed so quickly.

Erosion first becomes noticeable from the blackening or slight burning of the surface of the bore just in front of the chamber, and by the dulling or rounding off of the lands in front of the bullet seat. This blackening cannot be removed by any form of cleaning short of abrasion. When it first appears it has no apparent effect on accuracy. Gradually it incrèases and deepens until it develops into a rough, enlarged portion of the bore in front of the chamber through which the bullet has to jump materially before it encounters the lands. But even at this stage accuracy can frequently be restored by seating the bullet a little further out of the case, if that is permissible, so that the ogive of the bullet more nearly approaches the origin of the lands. There is now a faster falling off in accuracy and enlargement of the shot group, until finally so much of the rifling and bore has been eroded away that the bullet is no longer rotated, and all semblance of accuracy is lost.

Erosion is not a serious factor in our .30-06 service rifle in the military service because almost invariably the rifle becomes unserviceable from fair wear and tear before it becomes inaccurate from erosion. It is then returned to an arsenal for repairs, where the barrel is replaced by a new one, and any other repairs are made. The cost of a new barrel is a small fraction of the cost of the ammunition required to wear it out by erosion.

Erosion progresses much faster in machine guns than in rifles, because of the higher temperature induced by the rapid firing. It is important to know the accuracy life of machine gun barrels so we can determine how often they will have to be replaced. It is dangerous to fire over the heads of our advancing infantry with a barrel that is "keyholing" its bullets. Therefore most Government tests to determine the accuracy life of barrels have been conducted with a view to the use of the barrel in machine guns. The barrel is fired rapidly, machine fire, for a thousand rounds. It is then cooled by running water through it, and is tested for accuracy. This is then repeated until the dispersion has increased greatly, and an occasional bullet tips considerably and passes through the target sideways. The barrel is then said to be worn out. With present barrels and service (Cal. .30, M2) ammunition, barrels wear out in this manner after firing about 7,000 to 10,000 rounds.

The degree of accuracy demanded in a rifle barrel is much higher than in a machine gun barrel, because of the different uses that the two are put to. A barrel only half worn out for machine gun use might be incapable of surely striking a man target at 300 yards. Erosion tests have been made with .30-06 service rifles, firing a similar program to the above, but the rate of fire has been necessarily reduced to about fifteen to twenty rounds per minute or even less, due to the difficulty of operating the breech mechanism to extract

fired cases when the barrel is extremely hot. Barrels were cooled and tested for accuracy after each 500 rounds. In this manner barrels could be fired from 7,000 to 9,000 rounds before the dispersion had been increased to the point where the bullets would no longer strike in the standard 20-inch bullseye at 500 yards. The barrel was then considered worn out for Infantry use. In these tests, barrels wore out faster (about 7,000 rounds) when fired with the boat tailed bullet (Caliber .30, M1) than with the flat base bullet (Caliber .30 M2) which usually lasted about 9,000 rounds, because the form of the boat tailed bullet tends to funnel the hot and fast gases more in between the bullet and the bore, and gas cutting progresses faster. Also the M1 cartridge develops more heat than does the M2.

In this connection a very interesting experiment was conducted some years ago. The Massachusetts Rifle Association used to conduct a weekly rest match at 500 yards on their range at Walnut Hill. The rifle was fired as slowly as desired from a bench rest. Any rifle and telescope sights were permitted. This match was very regularly won by the late Mr. Philip Nutting of Cambridge, Mass. Mr. Nutting used a Model 1903 (Springfield) .30-06 Type T rifle, having the very heavy barrel of that type. His ammunition was the International Match load consisting of the 172 grain Frankford Arsenal M1 boat tailed bullet, and 36.4 grains of Hercules "Hi-Vel" powder with the F.A. No. 70 primer, muzzle velocity 2200 f.s. He was usually able to group ten consecutive shots at 500 yards with an extreme spread of not to exceed 6 inches. Mr. Nutting fired this rifle and load for 9,000 rounds before any falling off in accuracy was noticeable. He then seated his bullets projecting a little further out of the case which restored the accuracy, and in this way he continued to fire the rifle for a total of about 13,000 rounds with fine accuracy until the experiment was ended by his untimely death. Of course the International Match load develops a relatively low pressure and does not give as much erosion as the service load, but nevertheless this test teaches us a great deal.

From careful firing and experiments, by the writer and other skilled riflemen, we now have a very fair idea of the accuracy life of various rifle barrels under the conditions of ammunition and steel that now pertain. The following summary gives approximately the number of rounds that can be fired through a rifle barrel before a falling off in accuracy will be apparent to a skilled rifleman. The firing is presumed to be almost all slow fire, seldom firing more than ten rounds without a pause which allowed the barrel to cool. Proper care of the bore is presumed.

.22 Long Rifle. With regular ammunition and lubricated lead bullets, at least 250,000 rounds. During this firing the breech mechanism may have to be breeched up several times to restore tight

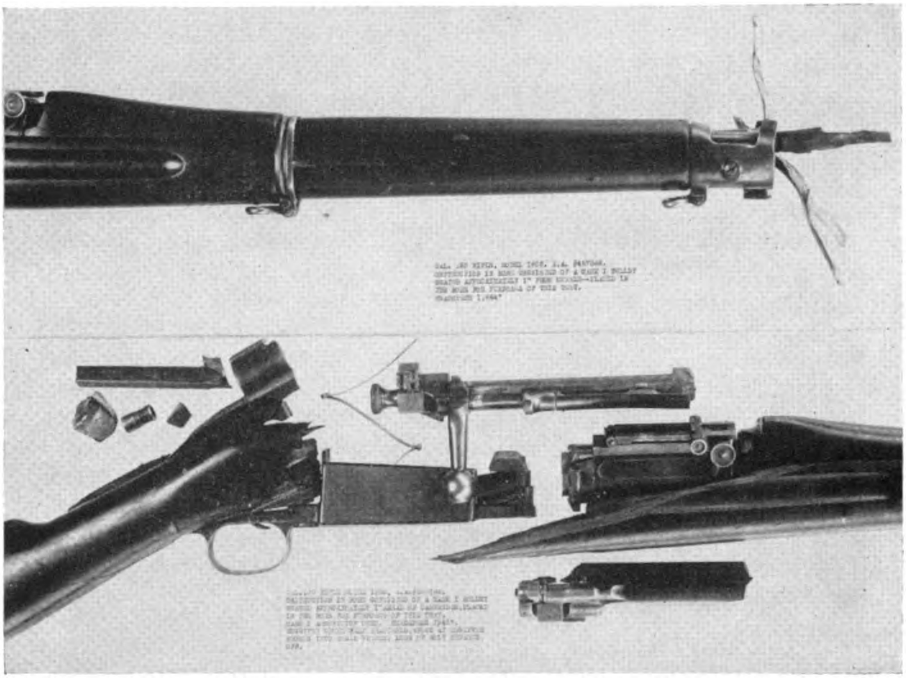


FIGURE 4B. EXCESSIVE PRESSURES

The upper cut shows the result of firing a rifle with an obstruction in the bore close to the muzzle, and the lower cut shows the effect of similar firing with the obstruction just in front of the chamber. The lower cut also shows the destruction that results from firing a cartridge having extremely excessive pressure.

All army rifles which have been "accidentally" injured in service are shipped to Springfield Armory for examination. Mr. A. L. Woodward, Engineer of Tests at that Armory for the past thirty years states that in ninety nine percent of these cases the accident has been caused by an obstruction in the bore, or by firing a wrong cartridge, that is an improper or wrongly sized cartridge, or one hand loaded to an excessive pressure. It is interesting to note that in a majority of these accidents an effort is made to conceal the real cause of the accident, but the evidence is always perfectly plain.

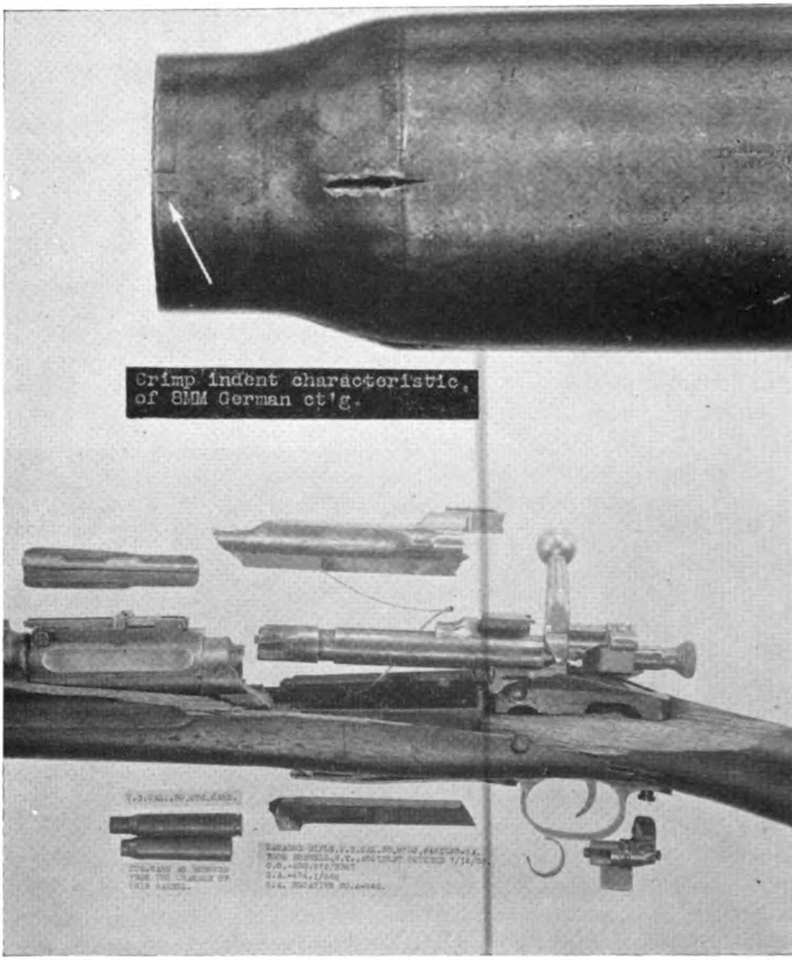


FIGURE 4C. EXCESSIVE PRESSURE

Showing the results of firing an 8 mm (7.9 mm) German Mauser service cartridge in a .30-06 Springfield M1903 rifle. The 8 x 57 German Mauser cartridge, sometimes called 7.9 mm, is the service cartridge adapted to the Model 1898 Mauser rifles used by the Germans in World Wars I and II. Since these wars these cartridges have become quite common in the United States. It is often possible to insert and load, and then fire one of these cartridges (and certain sporting versions of them, except only the older cartridge loaded with 236 grain bullet) in our .30-06 Springfield rifle, Model 1903, and in other rifles of this caliber, particularly if the chamber is a little large, or the headspace a little over standard. The 8 mm bullet measures about .321 to .323-inch, while the correct diameter of bullets for our .30-06 rifles is .308 to .309-inch. The result is that a terrific pressure is set up, and the entire breech action is shattered and demolished, and probably the shooter would be seriously injured.

The 8 mm and our .30-06 cartridges look very much alike, and this might contribute to an accident like the one pictured. However, on examining the two cartridges side by side it will be seen that the 8 mm case has a much shorter neck, and of course the stampings on the heads of the cases are different. All shooters and ballisticians should be familiar with the differences and the dire results which follow the firing of an 8 mm Mauser cartridge in a .30-06 rifle.

headspace due to mechanical wear. With regular ammunition and copper plated bullets, not lubricated, about 70,000 rounds. The writer has no data on the accuracy life with high velocity ammunition, but it is probably only slightly shorter than the above.

.22 Hornet. In the experiments incident to the development of this cartridge, at Springfield Armory, one test rifle with Ordnance steel barrel was fired approximately 20,000 rounds with no falling off in accuracy. This barrel was then unfortunately permitted to rust. Erosion apparently progresses very slowly with this light charge. Gilding metal jacketed bullets were used exclusively.

.22-3000 Lovell 2R. Chrome molybdenum steel barrels. 45 to 50 grain copper jacketed bullets. Powder charges; 17 grains du Pont No. 4198 or 15.5 grains du Pont No. 4227 powder, non-corrosive non-mercuric primers. We have quite a few reliable reports to indicate that these rifles can be fired at least 7,000 rounds before the extreme spread at 100 yards will begin to average over 1½ inches.

.220 Swift. Factory ammunition, 48 grain gilding metal jacketed bullet, M.V. 4140 f.s. The first of these rifles were made with the Winchester chrome molybdenum steel barrels, and the accuracy life was rather short, about 1,000 rounds to increase the extreme spread to 2 inches. It is understood that Winchester then adopted a barrel steel which gives greater resistance to erosion, and the accuracy life is now about 2,000 rounds. All slow fire. The accuracy life can be considerably increased by a slight reduction in the powder charge and velocity.

.22 Varminter. 50 and 55 grain copper jacketed bullets, M.V. 3600 to 3800 f.s. Mr. Gebby has a record of about 350 of these rifles that he has built. Only a few have been fired through their accuracy life, which apparently is about 3,000 rounds for gilt edge shooting. Apparently the more abrupt shoulder of this case, as compared with the shoulder of the .220 Swift case, causes more of the powder to burn within the case itself, or otherwise acts to reduce the throat erosion. But the difference in velocity between the two cartridges must also be considered.

.25-20 W.C.F. With smokeless ammunition and gilding metal jacketed bullets. Accuracy life not known closely but estimated to be at least 10,000 rounds. Prior to 1928, when all these smokeless cartridges were loaded with a chlorate primer, the bore was completely ruined in about 500 rounds, *and or* six months use, by corrosion which could not be prevented. Evidently this small powder charge did not dilute the chloride to any extent, and the "seeds" of corrosion were sown almost instantly.

.270 Winchester. With full charged factory ammunition. Mr. Jack O'Connor has observed a number of these barrels and states that the black erosion ring starts to appear after about 1,000 rounds, but

he does not give the accuracy life. It is probably at least twice this, that is over 2,000 rounds. The writer has one of these rifles with Winchester nickel steel barrel which has now been fired approximately 1200 rounds with full charged ammunition, and about 500 rounds with lead alloy bullets, and just a bare trace of blackening in the leade is beginning to appear. The accuracy is still unimpaired, and the barrel is far from worn out.

.30-30 W.C.F., .32 Special, etc. Factory ammunition and nickel steel barrels. Some little rapid fire. There is quite a mass of information that seems to indicate that accuracy suitable for short range deer hunting will be maintained for at least 15,000 rounds. But before this amount has been fired, the breech actions of lever action rifles have usually become unserviceable from the development of excess headspace unless returned to the maker for tightening up.

.30-40 Krag. When this was the service rifle of our Army the charge was a 220 grain cupro nickel jacketed bullet, 35 grains of W.A. nitroglycerin powder, and a chlorate primer. M.V. 2000 f.s. in 30 inch barrel. Accuracy life for military purposes was about 3,000 rounds, but bores wore out as much from corrosion as erosion, as a chlorate primer was used and water cleaning was then almost unknown. On the U.S. Infantry Rifle Team, 1903 to 1906, firing about half slow and half rapid fire, barrels became worn after 1,800 rounds so as to be unsatisfactory for competitive match shooting—partly from erosion and partly from corrosion. Note that W.A. was a rather hot nitroglycerin powder. It is probable that today with modern nitro-cellulose powder, N.C.N.M. primers, and gilding metal jacketed bullets, the accuracy life will be approximately 10,000 rounds slow fire.

.30-06 U.S. Accuracy life has already been commented on above.

.38 Special. Colt and Smith & Wesson Revolvers. Using lubricated lead bullets exclusively, there are several records that appear to indicate that these revolvers can be fired upwards of 200,000 rounds with no deterioration in accuracy or serviceability.

Shotgun Barrels. Apparently a shotgun barrel, properly cared for, wears out from the friction of the shot, and from the abrasives used to remove leading, and not from erosion. There are records of a number of British shotguns that had been fired hundreds of thousands of rounds, and then had to be retired only because the barrel walls had worn so thin as to be unsafe.

Gas Cutting

The amateur ballistician must be careful to differentiate between erosion and gas cutting, and corrosion. Erosion and gas cutting are very much the same, and can be told from each other only by location and extent or progress. We apply the term "gas cutting" to the

relative rapid erosion or "channelling" that takes place when gas rushes through a small orifice, such as the corners of the grooves where they start in the bullet seat or for an inch or so forward from the bullet seat. As we have seen, gas escapes all around the bullet as it passes from the case into the bullet seat and bore, and before the bullet has expanded sufficiently to shut off this gas escape between bullet and bore, but the last portions to be completely sealed are the corners of the grooves, and through these small holes gas escapes and cuts just as a stream of water, when nozzled down to small diameter, will cut mud. Gas cutting may also extend further up the bore when a small diameter bullet is used because such a bullet does not expand and shut off the gas escape so quickly. Also when gas escapes in this manner it also cuts the bullet, and while such cuts are minute on a jacketed bullet, they can often be seen on recovered lead alloy bullets which may have slightly melted channels opposite the gas cutting streaks in the bore.

What we usually term "erosion" is the burning of the bore, particularly the bullet seat and the leade, by the intensely hot gases which flow over the entire circumference as the bullet passes from case to bore. It occurs more or less evenly over the center of the grooves and top of the lands, but in the corners of the grooves it is deeper from the gas cutting. It occurs at a much slower rate than gas cutting. When a barrel is about half worn out we will usually discern gas cutting starting in the corners of the grooves in the leade, and then several thousands of rounds later we will probably notice the entire bullet seat and leade beginning to be blackened by erosion.

Corrosion

Corrosion, on the other hand, is rusting, caused by water, salt in the presence of water, or rarely acid in contact with steel. Corrosion may occur anywhere through the bore, or may extend from breech to muzzle. Without the presence of oil in the bore the telltale red color of rust will usually be seen on a patch pushed through the bore, but if there be oil in the bore the patch will usually come out black, when powder fouling is not present. Corrosion is more completely treated in Chapter XI. With modern ammunition, that is non-corrosive primers and normal changes of modern powder, and with proper cleaning not later than nightfall of the day the small arm is fired, corrosion will be practically non-existent. A very slight case of corrosion may occur from neglect of cleaning for several days, the bore may be wiped out and oiled, and no evidence of the corrosion will remain, and practically no harm has been done. But with repeated neglects of this nature the surface of the bore will first become slightly pitted with small spots, and later will be visibly roughened over most of the steel surface. When such corrosion is

present the bullet encounters more resistance as it passes through the bore, the pressure is increased, the bullet becomes slightly deformed so it is no longer a near-perfect gyrostat, accuracy deteriorates, and fouling increases.

There is no way to remove corrosion for it is not something deposited, but rather an eating away or destruction of the steel surface. But with all proper and normal modern ammunition and in all climates, corrosion can be prevented by proper care.

Apart from the above type of corrosion, which starts and proceeds rather slowly, rusting can be caused almost instantly by, so far as the writer knows, three conditions. First; by firing cartridges loaded with a small powder charge and chlorate primers, second; by abnormally small powder charges in almost any cartridge, and third; by pouring ammonia metal fouling solution into a bore still warm from firing. The first and second causes result each time in a light case of corrosion despite very prompt cleaning, and four or five repetitions of firing such ammunition results in very evident rusting and pitting. The third cause results in instantaneous ruination of the bore.

Friction

Bullet wear undoubtedly takes place, and is much more with metal cased bullets than with lubricated lead bullets. But in either case it appears to be inconsequential because, except in .22 rim fire, the bore will become inaccurate from erosion long before frictional wear becomes apparent.

The writer examined one .22 caliber Springfield M 1922 rifle in use in the proof house of the Remington Arms Company which had been fired 80,000 rounds with Remington Kleanbore .22 Long Rifle cartridge without any cleaning whatever, and was still as accurate as ever. Fortunately there was a star gauge record of this barrel when it was new, and star gauging after 80,000 rounds showed a uniform breech to muzzle enlargement on both lands and grooves of .0004 to .0005 inch, probably all frictional wear.

Friction of course materially affects the interior ballistics because it retards the movement of the bullet through the bore, increasing the pressure, heat, and barrel time. Friction can be reduced by lubrication, and this is done with lead alloy bullets, but in high pressure rifle cartridges a metal cased bullet must be used, and the powder gases are extremely hot. It is difficult if not impossible to find a lubricant that will not instantly be turned into carbon by the heat of these gases unless we use it on the ogive of the bullet, and such outside lubrication is objectionable for two reasons. First, in ordinary handling the outside lubricant is usually either wiped off the bullet, or it is liable to pick up dirt and abrasives and carry them

into the bore. Second, in hot weather, or when the barrel is hot from repeated firing it is difficult if not impossible to introduce an outside lubricated cartridge into the chamber without lubricating the chamber. A lubricated (oiled) chamber is a dangerous condition in any high power or high intensity rifle. It causes higher pressure by introducing a more or less thick film of grease between the case and the walls of the chamber, which prevents the case expanding normally when the cartridge is fired, and thus operates to increase the density of loading as though the powder charge were fired in a case of smaller capacity. At the same time the lubrication permits the case to slide easily to the rear through the chamber instead of sticking tightly to the chamber walls as long as there is a fair degree of gas pressure in the bore. As a consequence the back thrust on the breech block or bolt is very materially increased. This is clearly shown when using the oiled case method of taking pressures as is done with the S.M.L.E. rifle. (See Chapter II). The .303 Mark VII cartridge, when dipped in oil for taking pressures, gives a pressure of about 38,000 pounds per square inch. When, however, the cartridge is not oiled the pressure registered by the back thrust is only about 20,000 to 24,000 pounds.

These objections to outside lubrication do not apply with the .22 Long Rifle cartridge. This cartridge, being thoroughly outside lubricated, always lubricates the chamber in a very uniform manner, but the pressure is so low that no damage results. However, with all cartridges and calibers the chamber and bore should always be wiped clean and dry before firing the first shot. This caution is particularly necessary with a new weapon which always comes to its purchaser with the chamber and bore thoroughly greased to prevent rust. The presence of heavy grease in the bore acts as an obstruction, and the barrel is liable to burst. We often see service (.30-06) rifles that have been fired with the bore coated or nearly filled with heavy grease, and the barrel is almost always badly bulged or may be split wide open from breech to muzzle.

From the standpoint of safety there is perhaps no objection to firing the rifle with a very thin film of light oil in the bore, but this condition usually results in the first shot from the clean, slightly oiled bore flying slightly wild, and usually striking well outside the group of succeeding shots. The target shooter thus always wipes the chamber and bore of his rifle free from all oil before firing the first shot. The soldier or hunter may perhaps be excused for carrying his rifle in damp and rainy weather with the bore very lightly coated with a thin oil to prevent rusting, but the habit is not conducive to making a sure hit at mid or long ranges with the first shot.

In the days of black powder and paper patched bullets the well informed rifleman always fired his rifle with the bore clean and

slightly lubricated with thin oil, and he cleaned and slightly oiled the bore after each shot when it was possible to do so. This was because the paper patch was torn and did not remain on the bullet through the bore when the bore contained heavy black powder fouling. By "lightly lubricated with thin oil" is meant that condition resulting from swabbing the bore with a not too large flannel patch that has been very lightly saturated with oil not heavier than ordinary sperm oil.

Temperature

Normally velocities and pressures are established at and stated for air, gun, and ammunition temperature of 70° F. Desert temperatures of 120° F, and arctic temperatures of −40° F are not uncommon. The first means a rise of 50° above normal, and the latter a drop of 110° below normal.

Smokeless powder may be said to burn in the same manner as wood. The surface must be heated to the ignition point before it starts to burn. In extremely warm weather the cartridge and its powder will be warmer than normal, the powder will ignite quicker and more thoroughly, and will burn at a slightly higher pressure, giving more velocity. As a consequence the shot will strike slightly higher on the target. Riflemen frequently find that they have to reduce their elevation one to two minutes on extremely hot days. This is no alibi for the hunter who misses a deer, however, as two minutes means only two inches at 100, or four inches at 200 yards.

A word of caution seems in order here. A prescribed maximum charge of a certain powder for a certain primer, bullet, and cartridge may give a breech pressure of 50,000 pounds at normal temperature. A certain inexperienced experimenter may figure that the powder company has been over-cautious in setting such a maximum load, and that he can safely use one grain more powder. In fact he may have a friend who has been using such a load. He also finds that he can do so successfully, although he is probably getting a pressure of around 54,000 pounds. But along comes a very hot day in summer when he has been firing very rapidly, and his rifle barrel is extremely hot. He loads one of his heavily charged cartridges into this hot barrel and lets it remain there and "cook" for several minutes before he fires it. Or he may have left these cartridges exposed to the hot sun on the firing point for a long time. In either case the stage is all set for a very excessive and probably dangerous pressure. The soldier or hunter need not worry at all about carrying and using his rifle and normal ammunition in the hot desert or tropics, but he should avoid all very unusual exposure to heat.

Arctic cold acts in the opposite direction. The colder the cartridge is the more energy will be required from the primer to raise the

temperature of the powder to the ignition point. This loss in energy results in a slight loss in velocity and effectiveness.

The loss in velocity is somewhat dependent on the pressure level and type of propellant powder used. High power rifle cartridges such as .220 Swift, .270 Winchester, and .30-06 Government will show a loss in velocity of 3 to 5 percent when firing at −40° F. The same loss in velocity may also be expected with medium power center fire cartridges such as the .30-30 Winchester, .32 Special, .30 Remington, and .30-40 Krag, etc.

Revolver cartridges will generally show a loss in velocity of 5 to 8 percent when fired under the above extreme. This larger loss is often nullified by the fact that the gun in which the cartridges are loaded is generally carried in a holster close to the person, and the ammunition does not quite reach these low temperatures.

Medium and intermediate velocity rim fire cartridges such as the .22 Long Rifle, show velocity loss of from 8 to 10 percent at −40° F. The .22 caliber high velocity cartridges as represented by the Winchester Super Speed show a velocity loss of from 3 to 5 percent.

In the old days a large majority of shotgun shells were loaded with bulk smokeless powder. These powders would not withstand low pressures satisfactorily and as a result shells intended to be sent to cold climates were loaded with dense smokeless powders such as Infallible or Ballistite. Bulk smokeless powders have been discontinued by the loading companies, and only the dense or semi-dense are now being factory loaded. These powders perform satisfactorily at low temperatures. An average loss of approximately 5 to 8 percent is considered normal at forty degrees below zero.

Single base powders are generally used in loading center fire metallic cartridges. Double base powders which contain nitroglycerin and nitro-cellulose become very brittle when frozen. Under certain conditions a hot primer flash will fragment the powder grains, thus increasing the rate of burning and materially raising the pressure level. This condition was true with the old fulminate chlorate primers and it is still true with the present stainless or non-corrosive types whether or not they contain fulminate of mercury. This condition has resulted in the discontinuance of the general use of double base powders in center fire rifle sizes. The single base powders, having the single nitro-cellulose base, do not fracture at low temperatures, and no increase in pressure will result when fired under conditions of arctic cold.

The Revolver

Thus far we have described interior ballistics chiefly as it concerns the rifle and pistol, where the cartridge is loaded into a chamber integral with the bore. The revolver presents a slightly different

problem because the cartridges are loaded into the cylinder, which does not contain any rifling, and between the cylinder and breech of the barrel there is an opening across which the bullet must jump, and through which a small portion of the gas behind the bullet is exhausted.

Except where the weapon is constructed for the .22 Long Rifle rim fire cartridge, the cylinder of a revolver is chambered rather loosely for its ammunition so that the fired, straight, cartridge case can be extracted easily. In front of the chamber proper, the remainder of the cylinder bores are smooth and of the same diameter as the bullet. This smooth bored portion corresponds to the bullet seat in a rifle. For the .22 Long Rifle cartridge, the bullet of which is the same diameter as the outside of the mouth of the case, there is no shoulder at the forward end of the chamber proper, the diameter at the mouth of the chamber being continued to the front end of the cylinder. In all revolvers the breech end of the barrel is cut with a rather long leade, there being no rifling at the extreme breech end of the barrel, the lands then starting very shallow, and gradually increasing to full height, the resulting leade being approximately a quarter inch long. Thus the bullet, when it leaves the case and chamber, passes first through a short portion of the cylinder where the smooth bore is the same diameter as the bullet. It then jumps across the opening between the front of the cylinder and the breech of the barrel, entering the gradually sloping leade which guides the bullet centrally and in line into the rifling. In all first class revolvers, in good condition, the mechanical construction is such that the axis of the bores of the cylinder are in perfect alinement with the axis of the bore of the barrel. If, due to wear, accident, or faulty construction the cylinder axis did not aline with the barrel axis, one side of the bullet would be shaved off by the breech of the barrel as it jumped from cylinder to barrel, with very unsatisfactory or dangerous results. It is quite remarkable, considering how the lead bullet must jump such a distance from the chamber proper before it seats in the rifling, that such fine accuracy results. Only fine workmanship and exact alinement assure this.

As soon as the base of the bullet clears the front end of the cylinder, the opening between the cylinder and barrel is uncovered. This opening is small, not much larger than the thickness of a sheet of note paper. Nevertheless it is large enough to permit some of the gas expanding behind the bullet to escape, and thus not all of the gas generated is used to propel the bullet. But the gas is rushing straight forward at a very considerable velocity, and very little of it turns at right angles to exhaust through this opening. Of course some gas does escape, as is evidenced by the fouling of the front of the cylinder and the rear end of the barrel outside the bore, but

generally the amount is too small to have any appreciable effect in reducing the velocity, being usually not more than two or three per-cent. A direct comparison has been made with the .45 Colt Automatic Pistol (where the chamber is in the barrel), and the .45 Colt Model 1917 Revolver, both firing the .45 Colt Auto cartridge. The average muzzle velocity in the pistol was 787.9 f.s., and in the revolver 800.6 f.s. The reason why the velocity in the revolver was higher than in the pistol, instead of the reverse as might be expected, was because the combined length of barrel and cylinder in the revolver was 7.095 inches, while the corresponding barrel length in the pistol was only 5 inches. But the test shows that there is little material loss of velocity in the revolver due to escape of gas between cylinder and barrel.

The combined length of cylinder and barrel of the revolver is comparatively short, therefore a very quick burning powder must be loaded in the cartridge in order to generate enough gas in this short length to give the bullet enough velocity to do the work it is intended to do—to range, to penetrate, and to kill. Also the pressure must be quite low, because the walls of the chambers in the cylinder must be relatively thin to avoid the revolver being too heavy. In the older types of revolvers the breech pressure should not exceed 9,000 to 10,000 pounds, not only because of their thin chamber walls, but because these older revolvers were and still are often constructed of steel that does not have a notably high tensile strength and elastic limit. With such weapons and cartridges that are suitable and safe for them, the muzzle velocity does not usually exceed 900 f.s., and normally is around 800 f.s.

In more modern revolvers, such as those for the .38-44 High Speed cartridge and the .357 Magnum cartridge, the cylinder walls are thicker because a cylinder of the outside diameter for a .45 cartridge is used and is bored only to .35 caliber, and also a more modern steel of greater strength is used. The chamber pressure in the .357 Magnum revolver is about 35,000 pounds, and the muzzle velocity is 1510 f.s.; the highest pressure and velocity in any revolver.

Automatic pistol barrels are made of steel of greater strength than that used in older revolvers, and pressures and velocities can be much higher. In the Colt Super .38 Automatic Pistol the breech pressure is about 25,000 pounds, and the muzzle velocity in the 5 inch barrel is about 1200 f.s. With the .45 Colt Automatic Pistol, Government Model, the pressure is about 14,000 pounds, and the muzzle velocity about 800 feet per second.

Interior Ballistics—Numerical

By means of intricate mathematical formulas it is possible to calculate the pressure and velocity in any barrel with any load.

However, such calculations hardly come within the province of this work. Mathematical calculations of pressure and velocity are quite satisfactory in the case of heavy ordnance (cannon) where practical determination in the process of original design is so tedious and expensive. But the methods of attacking the numerical problem require considerable modification in the case of rifles, and have not been so successful, nor have they given such accurate results as with heavy ordnance. With small arms it is difficult to calculate or evaluate the effect of forcement, that is the force required to drive the rapidly expanding and moving bullet through the leade into the rifling; the loss in energy of powder gases in heating the barrel; and the friction in the bore at the velocity developed. Therefore pressures and velocities with small arms have usually been obtained by constructing a test gun and cartridge, and then using a pressure gauge and chronograph, which method is not too expensive or tedious. Or, in the process of design, approximate data can now be obtained by comparison with very similar small arms and cartridges of known performance.

CHAPTER II

Determination of Pressure and Velocity

PRESSURE and velocity are the milestones which measure the ability of a small arm to do work—to propel the bullet or charge of shot to a distance. The safety of the weapon is measured in terms of pressure—pounds pressure per square inch; and its energy and trajectory in terms of velocity—feet per second of travel. We have already seen that pressure in small arms cannot be computed with the desired degree of accuracy. Neither can velocity be computed with accuracy, although should we happen to know or determine the trajectory we could figure back the velocity within fairly close limits.

In practice, small arms pressures and velocities are always measured by test with certain instruments. As the result of long experience, certain instruments have been developed for these purposes, have been standardized, and are in almost universal use among all ballisticians and manufacturers of small arms and ammunition. The precise method of using these instruments has also been standardized. Results obtained in any one well established ballistic laboratory will therefore agree quite closely with those obtained in other such laboratories. But an individual experimentor cannot hope to obtain comparable results unless he uses the standard instruments, materials, and methods.

Pressure

The almost universal method of measuring pressure within a gun barrel, both in America and abroad, is by means of a crusher gauge in which the gas pressure is permitted to compress a cylinder of copper or lead of standard dimensions and composition. The pressure is indicated by the amount of compression (shortening) of the cylinder.

The crusher gauge is a mechanical device designed to hold the copper or lead crusher cylinder so that the gas pressure generated in the cartridge and barrel can be applied to compress the cylinder. Two types of these gauges are in common use with small arms.

In America, the commonly used gauge admits gas to compress the

crusher cylinder through a port or hole drilled in and through the chamber or bore of the weapon, termed the "radial" system. In England the "oiled case" method is used, where the cartridge case is oiled, and the crusher cylinder is contained in the head of the bolt or breech block. The rearward motion of the oiled case, when fired, compresses the cylinder. We will describe the American type first.

Radial Pressure Gauge

A separate pressure gun and gauge has to be provided for each caliber of gun and type of cartridge, although the copper or lead crusher cylinders are alike for all. Copper is used for cylinders to measure rifle pressures where the resulting pressures are high. Lead cylinders are used for shotguns and sometimes for revolvers where the pressures are relatively low. Factories and ballistic laboratories obtain their crusher cylinders only from one source, so as to assure uniformity in materials and size.

To construct a pressure gun and gauge, a hole is first drilled through the walls of the chamber or bore of the barrel. A barrel heavier than the standard is usually but not necessarily employed, and this barrel, with its attached breech action, is usually arranged so that it can be held in a fixed rest. If the barrel is to be used for measuring pressures with a standard cartridge, care is taken that it has a bore and chamber of exactly standard dimensions for that cartridge. The drilled hole is termed the "piston hole."

A strong and carefully fitted housing or arbor is then placed around the barrel and over the piston hole (see Figures 6 to 8), and it carries an adjustable anvil that can be moved up and down by means of a strong and large set screw positioned above it.

The cartridge whose pressure is to be measured has a small hole drilled through the wall of its case very slightly smaller than the piston hole (to prevent the gas check from dropping into the case) and this cartridge is loaded into the pressure gun with this hole upward and so it will register with the piston hole. A copper gas check in the form of a small cup is then inserted in the piston hole from above, with its concave side down, so it lies at the bottom of the piston hole. A hardened steel piston, which is a push fit in the piston hole, is then inserted on top of the gas check. The copper crusher cylinder is placed on top of the piston, and the anvil is then placed on top of the cylinder. The set screw is then screwed down on the anvil with finger pressure so that it holds the anvil tight against the crusher cylinder, there being no looseness or play anywhere, and all parts being so strong that there will be no give to them.

The gun is then fired. The gas pressure, operating through the hole in the cartridge case, forces the piston upward, and compresses, or shortens, the copper or lead crusher cylinder against the anvil.

The fired case is then extracted, the set screw is loosened, the cylinder is carefully removed, the piston is removed, a short rod is inserted into the piston hole to force out the gas check which is removed from the chamber into which it falls, and the gun is then ready to be loaded for a second shot. Usually five pressure shots are fired, and a mean is taken of the five recorded pressures.

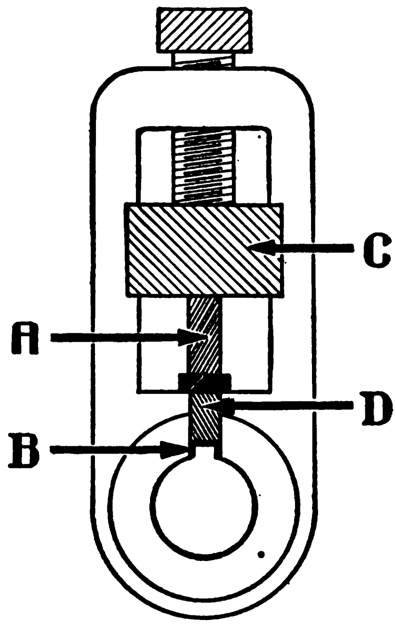


FIGURE 6. AMERICAN CRUSHER TYPE PRESSURE GAUGE
A—Copper crusher. B—Gas Check. C—Anvil. D—Piston.

When the crusher cylinder is removed from the gauge its length is measured with a micrometer caliper, and this length is compared with its standard length before compression. From a "tarage table" the pressure is then read off in terms of pounds per square inch. The data for this tarage table is prepared by compressing standard crusher cylinders statically in an arbor press arranged with a beam scale to show pressure (weight) applied, and recording the compressed length of the cylinder. Thus if the pressure gun compresses the cylinder to the same length that the arbor press compresses it with a scale pressure of, say, 45,000 pounds, the pressure obtained in the gun is said to be 45,000 pounds.

Sometimes the cylinders may be "pre-compressed"; that is, if a pressure in the gun of 48,000 pounds is expected, the cylinder may first be compressed in the arbor press by an applied pressure of

30,000 or 40,000 pounds, and this slightly shortened cylinder is then used in the pressure gun. When the pressure gun is fired the piston moves exactly as the bullet moves. It starts at the extremely high velocity of the bullet, and it continues its fast travel, slightly slowed down by the work it is doing, until it compresses the crusher cylinder as much as it can—possibly a movement of $1/16$ or $1/8$ inch. This rapid movement results in a quick and hard blow on the cylinder, the frictional heat is high, and the copper is heated and flows, and is compressed more readily when hot. Therefore the copper cylinder in the gun is probably compressed more in the gun than it is in the arbor press where the pressure is applied slowly. This is taken into consideration when preparing the tarage table. It is thought that pressures taken with pre-compressed coppers are more truly indicative of the actual pressure than those taken with uncompressed coppers because the anvil is screwed down on a cylinder that has already been compressed and shortened to a considerable degree, hence the piston does not have to travel so far, its momentum does not give such a severe blow, and not so much frictional heat is developed.

The amount of compression of the cylinders naturally depends upon the degree of hardness of the metal from which the cylinders are made. Extreme care is taken to make them of uniform hardness, but nevertheless each batch of cylinders received from their manufacturer is tested by applied pressure, and if necessary a separate tarage table is prepared for that particular batch.

Such a pressure gauge with the piston hole drilled through the chamber of the barrel will give the maximum breech pressure. Multiple pressure gauges are also made where the piston holes are drilled into the bore of the gun at varying distances in front of the chamber; such gauges will record the pressure in the barrel at the instant the bullet has cleared that piston hole. Thus we can determine at what point in the forward progress of the bullet the maximum pressure occurs, what the pressure is at various points in the bore as the bullet proceeds forward, and how the pressure is sustained with various types of powder—regular or progressive burning. Figure 3 shows a record obtained with a multiple pressure gun.

Oiled Case Pressure Gauge

The English system of oiled case pressure gauge is quite different, but the principle is the same. Figure 10 shows the details of this gauge. A normal undrilled barrel is employed. The outside of the case of the cartridge to be tested is thoroughly oiled before insertion into the chamber so it will slide easily to the rear when fired and will not "hug" the chamber walls. A special bolt is used which has a steel piston, or "pad" as the English call it, at the face of the bolt

and pressed tight against the head of the case. Just behind the piston a hollow copper crusher cylinder is placed, which hangs horizontally on the striker pin, and its rear surface abuts against a surface on the special bolt which acts as an anvil. When the gun is fired the oiled case moves quite freely to the rear, exerts its pressure on the piston, and the latter compresses the copper crusher cylinder against the anvil surface of the bolt. The shortened copper is then measured and the reading compared with the tarage table to obtain the breech pressure, as in the American method. While the tarage table usually

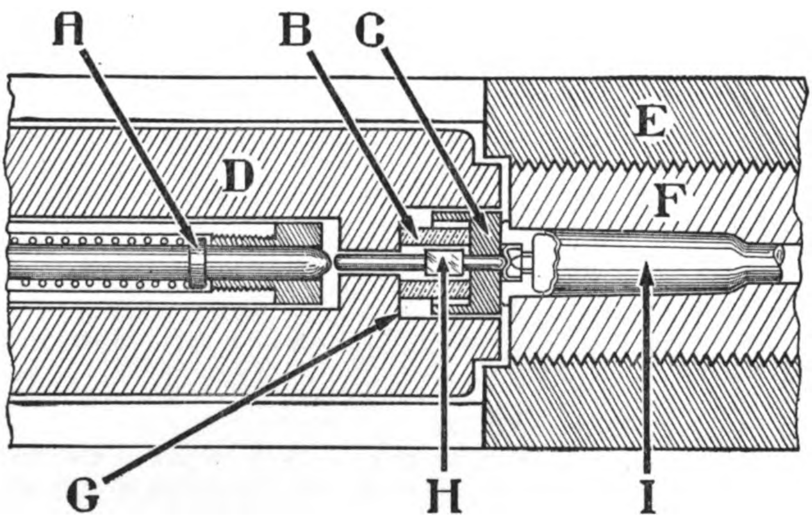


FIGURE 10. BRITISH OILED CASE PRESSURE GAUGE—DIAGRAMMATIC
From British "Text Book of Small Arms 1929"
A—Firing pin. B—Copper. C—Piston. D—Bolt. E—Receiver. F—Barrel. G—Anvil. H—Striker. I—Oiled case.

reads in terms of pounds per square inch, we could just as easily compute it in terms of pressure on the sectional area of the bolt head and get the back thrust on the bolt.

Crusher type pressure gauges probably do not indicate true pressures, but rather relative pressures. But gauges of this type have been in almost universal use for the past seventy years, and the pressure figures obtained with them, whether we call them "pounds per square inch" or "pressure units," have been used in the development, design and control of all modern ordnance. Every manufacturer has thousands of pressure figures determined with crusher gauges, and based on them small arms have been built and ammunition loaded in a perfectly satisfactory manner. And we also know

that when the crusher gauge shows a reading indicating an unsafe pressure we always get into trouble.

The Piezo Gauge

A more modern type of pressure gauge that is coming into extensive use is known as the electric strain gauge, or the "Piezo quartz crystal gauge." When pressure is applied to a quartz crystal in a certain direction with respect to its grain, an electromotive force is developed which is in direct proportion to the pressure. The Piezo gauge consists of layers of quartz crystals prepared so that their flat surfaces lie correctly with respect to their grain. Between each two crystals is a metal plate. The assembled gauge is placed in an arbor with piston and anvil similar to that used in the crusher system. The metal plates between the crystals have wires attached which transmit the electromotive impulse to the recording instrument. This instrument will record in the form of a curve both the maximum pressure and the time required to build the pressure up to the maximum, and it indicates pressure more accurately than the crusher gauge. But it must be handled by technicians who are specially trained to its use and familiar with the difficulties that may be encountered. The cost of the apparatus, the highly technical labor involved, and the time required to operate have thus far restricted its use.

Estimated Pressures

A very rough and crude indication of pressure can be obtained from an examination of the fired case. At least we can usually tell whether the pressure is low, approaching the maximum permissible, or prohibitively high. We must repeat again what we have said several times throughout this work, that the brass case is the weakest link in sustaining pressure. If the case stands the pressure in a satisfactory manner, that pressure is perfectly safe in the gun. The first indication of excessive pressure is usually the swelling of the head of the case, or swelling of the sides just in front of the head, resulting in more or less difficulty in extracting it from the chamber. As it is possible to come upon a case that has faulty or soft anneal, too much emphasis should not be placed on only one swollen case, but if the cases regularly swell it indicates that the pressure is at least too high for those cases, and therefore too high for the gun they are used in. When gas starts to leak back around the primer it indicates still higher pressure. Swelled heads and leaky primers are sure indications of excessive and dangerous pressures. However, leaky primers are occasionally caused by the primers being too small for the primer pocket in the case, and thus do not invariably indicate high pressures.

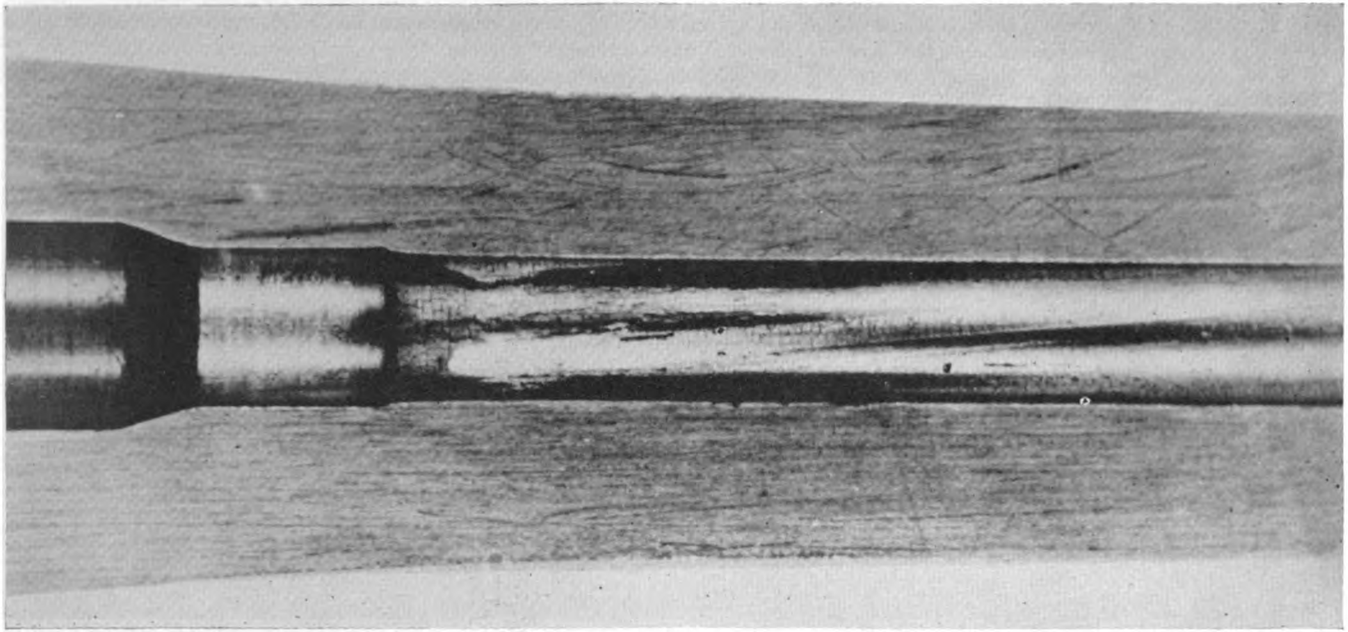


FIGURE 5A. EROSION IN .30-06 SPRINGFIELD RIFLE

This illustration shows the result of firing 5,145 rounds of cartridges loaded with the 172 grain boat tailed bullet and 46.6 grains of duPont I.M.R. No. 17 nitrocellulose powder.

Note that with this nitrocellulose powder the erosion at the bullet seat just in front of the chamber is less, but the eroding or washing away of the lands has been continued further up the bore than with the use of nitroglycerin powder, as shown in Figure 5B. This is exactly what we would expect, for the nitrocellulose is a cooler burning powder but develops its pressure peak further ahead of the chamber than does the nitroglycerin powder.

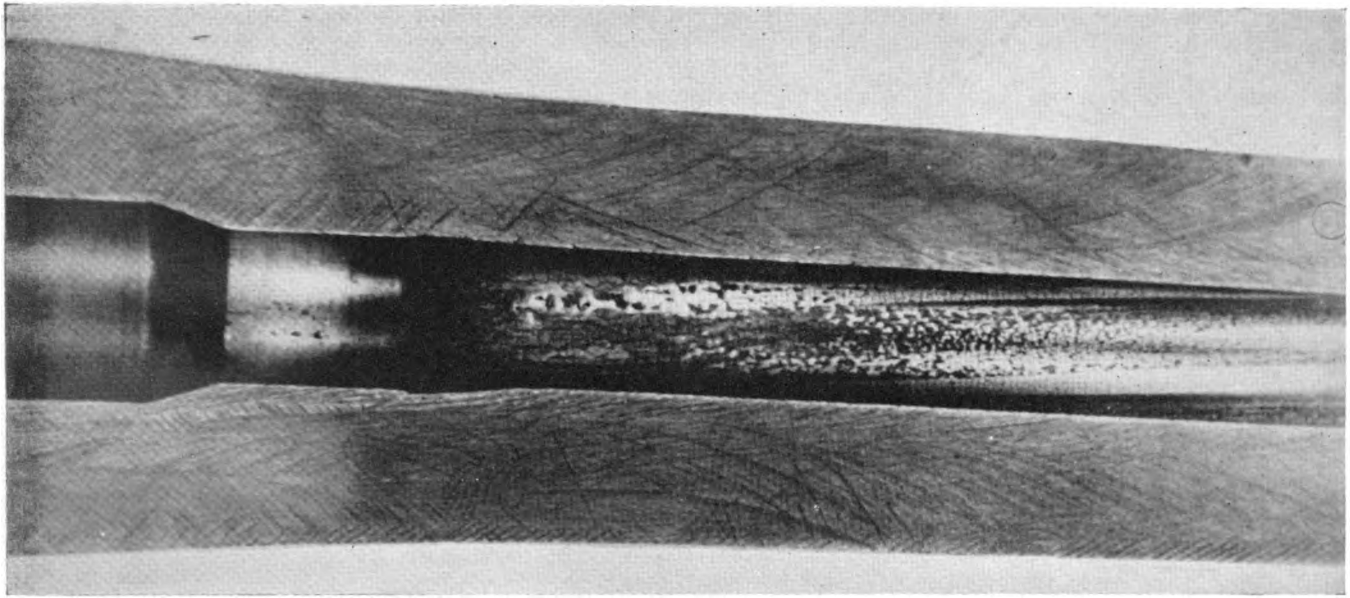


Figure 5B. Erosion in the .30-06 Springfield Rifle

This illustration shows the erosive results from shooting 4,582 rounds of cartridges loaded with the same 172 grain boat tailed bullet and 44.5 grains of Hercules HiVel nitro-glycerin powder.

Both the above and the bore shown in Figure 5A show more erosion after the number of rounds fired than a rifleman would commonly encounter at the same stages. These barrels were fired very rapidiy in stages of 500 rounds, with accuracy tests between stages, and the barrels became extremely hot. In normal use a rifleman would never get his barrel so hot, and erosion would not progress so fast. With both barrels, the rifling was practically perfect through the muzzle half of the bore at the conclusion of the test, showing that the friction of the bullets had played little part in the barrel wear.

If a primed case, without any powder in it, be indented by the firing pin, the indentation will always be deep if the mainspring blow and firing pin protrusion be normal. If the case be loaded with a light charge, the low pressure will set the indentation back slightly so it will not be so deep. A full charge will set the indentation back still more so it will not be nearly so deep. Full charges, roughly approaching 45,000 to 50,000 pounds pressure in high power rifle cartridges, will also frequently cause the indentation to extrude around its diameter slightly back into the crevice between the bolt face and the point of the striker, and into the firing pin hole. The indentation appears to have a slightly raised rim around it. Such extrusion depends upon the hardness of the metal of which the primer cups are made, and some will not show any extrusion at 50,000 pounds, while others may show considerable at 40,000 pounds. Extruded primers are not a sure indication of excessive pressure, but they are an indication of approach to the maximum permissible pressure, or they may indicate that the firing pin is too small, or that the firing pin hole in the bolt is too large.

The above indications, of course, depend not only on the pressure, but on the anneal or hardness of the brass in the case and primer. They are comparable only when the metal is of equal hardness. Informal tests and comparisons should be made with cases and primers of the same manufacture. If one is developing a charge, say, with Winchester make of case and primer, then it would be well to fire a fully charged factory cartridge of Winchester make, and use it for comparison. A developed charge should then give about the same appearance and dimensions to its fired case as the factory cartridge gives, thus indicating a pressure approximately the same.

The hand loading of cartridges for ballistic test work or other purposes, and the precautions relative thereto with respect to pressure will be discussed in a subsequent chapter.

Velocity

There are a number of varying types of instruments that are used for measuring the velocity of a bullet in flight. The earliest instrument so used, and the first instrument of precision to be applied to gunnery was the Ballistic Pendulum invented by Benjamin Robins, an Englishman, about 1740. As Robins constructed it, it consisted of a pendulum having for a bob a very heavy block of wood. The bullet was fired into the block and drove it backward. The length and weight of the pendulum and the weight of the bullet being known, and the swing of the pendulum being recorded, it was easy to calculate the striking velocity and energy. The pendulum has been much refined since those days and in its present development is a satisfactory and accurate instrument for recording velocities of

projectiles and recoil. It is, however, not much used for the first purpose because it is much more tedious in use than the modern chronograph.

The Ballistic Pendulum

Modern ballistic pendulums are installed on the private range of Lord Cottesloe at Wistow in England, and on the range of Mr. J. Bushnell Smith at Middlebury, Vermont. The bob of the Smith pendulum consists of a hollow metal cylinder about six inches in diameter and six feet long, filled with oiled sawdust. The bullet penetrates into the cylinder bob and is caught and brought to rest by the sawdust. The bob is further weighted by a box of bullets of various weights. If a 100 grain bullet be fired into the pendulum, a bullet of that weight is extracted from the box, thus maintaining the weight of the bob. The bob is suspended by chains with knife edge bearings, and when struck by a bullet it swings to the rear, when a vernier stylus records the length of the swing. From that length, the velocity is read off from a prepared table. This pendulum has given results comparing in accuracy with those obtained with the Le Boulenge chronograph. When a shot is fired it is necessary to have an assistant at the pendulum to record the swing and to remove a bullet of equal weight, or else for the firer to proceed to the pendulum to make the record, and as the Smith pendulum is located 200 yards from the firing house the latter procedure is rather tedious.

Mr. J. Bushnell Smith gives the following description of his ballistic pendulum used as a chronograph:—

We based our design on the Hodsock pendulum, as described in "Hodsock's Ballistics," but we went considerably further than the Hodsock in the way of refinements, mainly in the knife-edges, vernier, etc.

We made the main body tube of the bob of a six-foot length of aluminum well casing, six inches in diameter. Of course any material would do, but we wanted to keep the weight of the bob under 100 pounds, whereas the British figure called for a much heavier bob. In fact our first experiment was made with a heavy steel tube, with heavy flanges, and to the original weight. This, we found, was all right for bullets of 150 grains and heavier, but the 45 to 75 grain weights that we were primarily interested in, did not give the pendulum a great enough swing. You can see where the margin of error in measuring the swing, or the percentage of error, would be greater in a one inch swing than it would in, say a 2½ to 3 inch swing, for the same given impact. Hence the aluminum tube and the lighter bob.

We made our piano-wire suspension about six feet high, there is

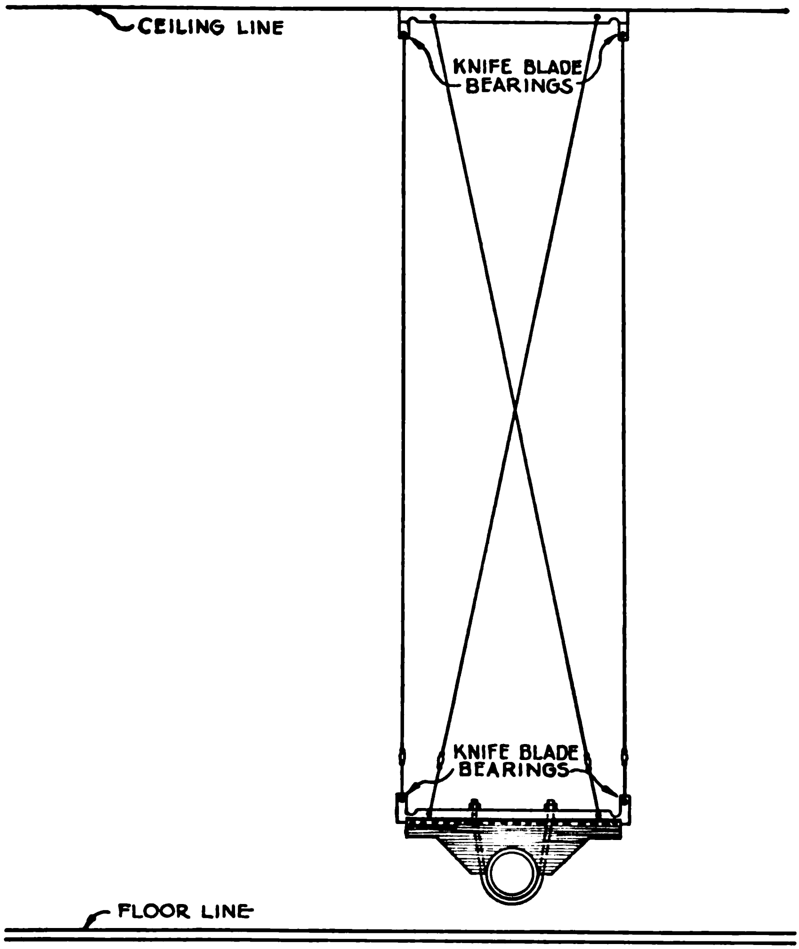


FIGURE 11A

nothing particularly desirable about this—it could have been three or a dozen feet as far as the working of the rig matters, but six feet gave us a nice motion, not too quick or jerky, and still not so long that it required too high a building.

The original dope called for the bob to be suspended on straight knife-edges, top and bottom. This we found impractical as the sharp impact of a high velocity bullet would slide the bob a little on the knife-edges before it started to swing. This of course upset all the readings of the vernier. We got around this by grinding the knife-edges so there was a small radius at the contact points. In other words making a sort of "male and female" knife-edge contact.

We were fortunate in obtaining a swing of 40 per minute, as this simplified figuring the formula, as the time of a single swing is one of the constant figures used. However this is unimportant except in convenience.

The vernier is accurately made, to read in thousandths of an inch. We made the rod that carries the sliding scale of the vernier of duraluminum, to keep it as light as possible, and worked some colloidal graphite into it and its bearings, to reduce the friction to a minimum. Still this very light outfit gave us a frictional loss enough to upset our readings if we let the vernier rod slide the whole travel of the bob. So our method on a test of a new load would be to fire one shot to determine the approximate distance of swing, and then set the vernier so that it would just about contact at the end of the bob swing, allowing a total movement of the vernier of not over a tenth of an inch or so. This way we got much more consistent and accurate readings.

The whole set-up was so sensitive that we had to house it in a practically air-tight chamber, as the slightest air disturbance would upset everything. The little house that contains the pendulum is set on and bolted to four large cement blocks set in the ground. On the "business end" that we fire into we have two heavy steel plates, set about six inches apart, and with a five-inch hole through both. This hole, lined up with the end of the six-inch bob, assures that any bullet that gets by the plates will land into the bob, and not wreck our installations in the case of a wide shot. The tube of the bob is, of course, filled with oiled sawdust. This has handled everything we have tried on it, including the .375 H & H Magnum rifle cartridge.

As the weight of the bob and suspension equipment—in grains—is an important figure in the calculation of velocity, this must be kept uniform. We do this by a few removable lead weights, and a box of 100-grain bullets, included in the total weight of the bob. As we fire a certain weight of bullet into the bob, we remove the same weight from the bob by taking out one or more of the 100-grain bullets in the box. We get at it closely enough in this way, for with light weight bullets of the Swift variety, we fire twice and then remove one bullet, etc. When we have used up the box of bullets we then remove one lead weight, and replace it with the same weight of bullets, and start over. This way, and for the amount of shooting we do, we only need to repack the bob about once a year.

When we built the outfit we were working with the "8-S" bullets, and trying to determine which type point gave us the best sustained velocity, so we set the pendulum 200 yards from our bench rest. Then we could fire a few shots at 25 feet, and a few more at 200 yards, and check one design bullet against another, figuring the percentage of loss of each. We knew the pendulum would give us an

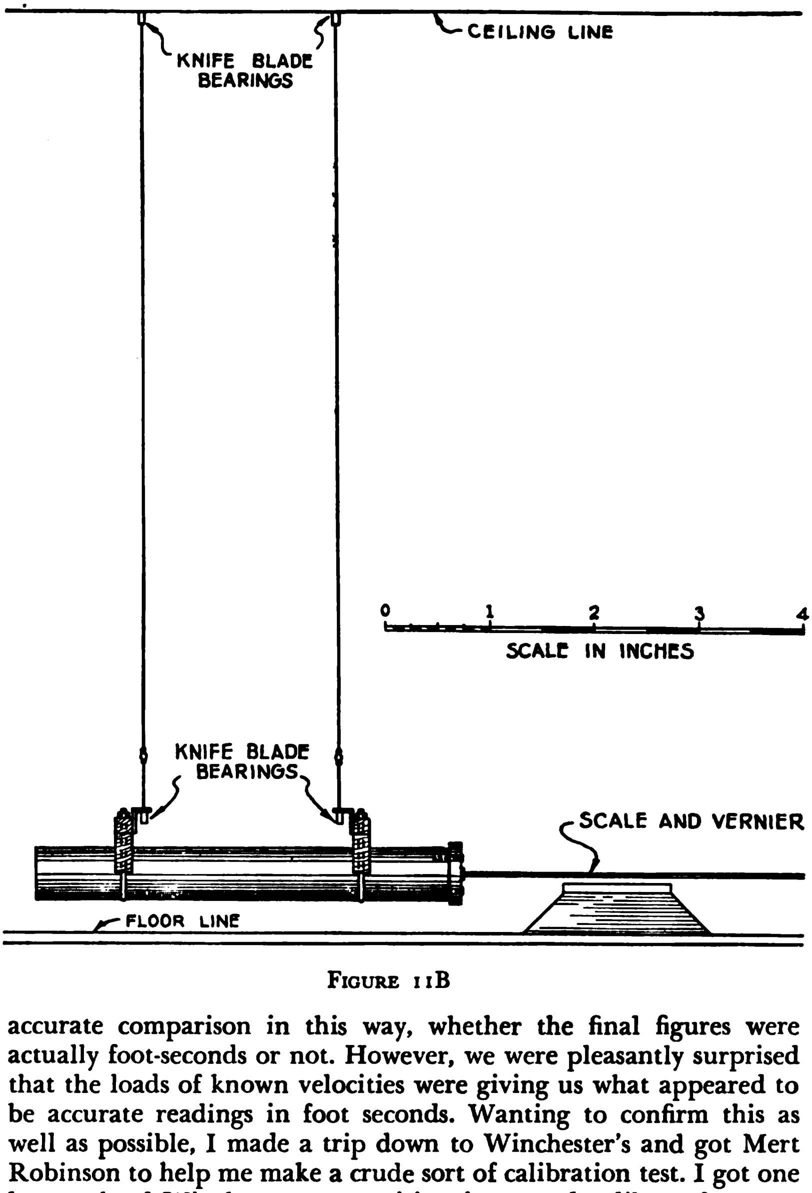


FIGURE 11B

accurate comparison in this way, whether the final figures were actually foot-seconds or not. However, we were pleasantly surprised that the loads of known velocities were giving us what appeared to be accurate readings in foot seconds. Wanting to confirm this as well as possible, I made a trip down to Winchester's and got Mert Robinson to help me make a crude sort of calibration test. I got one box each of Winchester ammunition in several calibers, from .22 Long Rifle to .30-06, and had Mr. Robinson chronograph five rounds from each box. Then I brought up the remaining rounds and fired them on the pendulum This way eliminated any possible variation in different lots of factory loads. I did the shooting and

had Charlie Morse take the readings, and he did not know the Winchester figures, and in some instances even what calibers I was shooting. In this way his readings could not possibly be influenced by the known figures I had obtained at Winchester's. As I now remember it we used .22 Long Rifle, .22 Hornet, .25-35 W.C.F., .220 Swift, .250-3000, .270 Winchester, and .30-06. In comparing our results with the instrumental velocities obtained by Mr. Robinson, our widest variance from his figures was 45 f.s., and that with the high velocity .270 Winchester load. That was the 100 grain load, and we got a mean velocity of 45 f.s. higher than the figures he gave us. This was remarkable, for as Mr. Robinson said, the difference between the velocity of the same load fired in two different barrels is often greater than this.

Below you will find the formula for figuring the data. You will note that the constant figures in the formula can be made about anything desired—to figure out individual shots easily and eliminate the working of too complicated figures. This is done by shifting the weight of the bob.

Formula: V equals $\frac{W}{w} \times \frac{P}{12T} \times A$

V—Velocity.
W—Weight of bob in grains.
w—Weight of bullet in grains.
P—3.1416
T—Time of a single swing in seconds.
A—Amount of swing.

Constant is $\frac{W \times P}{12T}$

Velocity is $\frac{\text{Constant} \times A}{w}$

To obtain desired constant by adding weight to bob, divide the desired figure by $\frac{P}{12T}$. Carry this out to the seventh decimal place. This will give the total required weight of the bob for the desired constant figure.

Rotary Chronograph

Another form of velocity recording instrument consists of a constant speed electric motor of known velocity of rotation, with a large circular paper disc secured to each end of the lengthened shaft. The bullet is fired through the two discs while the motor is

rotating them. Coincident index lines are placed on each disc. The bullet will pierce the first disc at a certain distance from the index line, and will penetrate the second disc at a certain greater distance from its index line. Knowing the distance between the two discs, the speed of rotation, and the distance apart of the bullet holes, the velocity can be calculated. This form of instrument is illustrated in Dr. Mann's work "The Bullet's Flight." It is possible for an electrical engineer or other technical experimenter to construct such a chronograph for his own use without prohibitive expense, and to use it successfully. Complete instructions for making one of these chronographs will be found in the article by Thomas N. Lewis and C. L. Quick, published in the November 1932 edition of The American Rifleman, and the article by Dr. James F. Brady in the April 1942 issue of the same magazine.

The most commonly used instruments for measuring the velocity of small arms bullets and shot are the Le Boulenge and Aberdeen chronographs. They measure the velocity by means of two electric circuits. The first circuit is made or broken several feet in front of the muzzle, and the second circuit is made or broken at the target. The chronograph measures the time interval between these two makes or breaks, and this interval gives the time of flight between the two locations.

The Le Boulenge Chronograph

The Le Boulenge chronograph is the older of the two and is or was in constant use in all arms and ammunition factories and ballistic laboratories. It was invented by a Belgian officer about 1870. There are two electric circuits. One runs through a very fine wire stretched across the path of the bullet about three feet in front of the muzzle of the gun (to be beyond the effect of muzzle blast) and then through an electro-magnet in the chronograph. This circuit is broken by the bullet as it leaves the muzzle and cuts the fine wire. The second circuit runs through contact points at a steel plate at the target and then through a second electro-magnet in the chronograph. When the bullet strikes the steel plate that plate moves to the rear and breaks this circuit. The chronograph measures the time between the two breaks, that is the time it takes the bullet to travel from a point three feet in front of the muzzle to the target, in the following manner. See Fig. 15.

The chronograph consists of a stout brass pillar about a yard high, mounted on a solid work bench, and adjustable to the vertical by three levelling screws. The pillar carries two electro-magnets, M1 and M2. Each magnet has a vertical pole piece capable of holding (when the current is on) the falling rods marked R1 and R2. These rods weigh just under a pound each, and are provided with soft iron

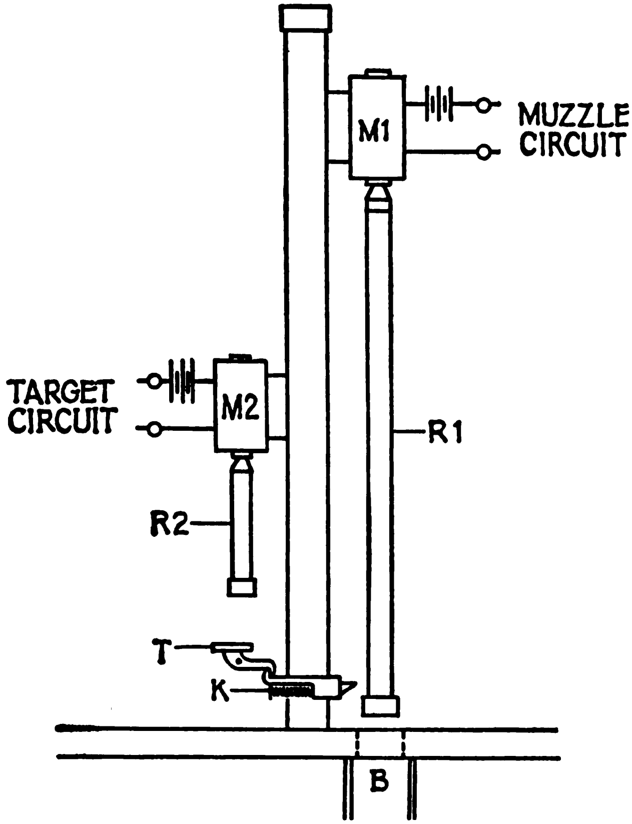


FIGURE 15. LE BOULENGE CHRONOGRAPH—DIAGRAMMATIC

tips at the upper end so that the poles of the magnets will attract and hold them. The long rod, R1 is further covered with a removable jacket of zinc which surrounds it from tip to tip. The current passing through the magnet M1 holds the tip of rod R1 to the pole of the magnet, and when this circuit is broken by the cutting of the thin wire in front of the muzzle, the long rod R1 falls vertically until it is caught in a leather boot B located below the work bench. The circuit through the magnet M2 also passes through the target, and when the bullet strikes the latter the short rod R2, which has been adhering to its magnet, falls vertically and strikes the trigger T which releases the spring actuated knife K. K then flies forward and makes a sharp cut in the zinc jacket on rod R1 while that rod is falling.

To prepare the instrument for a shot, a special switch opens the circuit to both magnets and thus makes a zero mark on the rod cor-

responding to a bullet of infinite velocity. The circuits are then closed, the rods replaced, and the trigger is recocked. The operator at the instrument then signals to the firer at the gun that all is ready for a shot.

The gun is then fired and the bullet breaks the thin wire in front of the muzzle, breaking the electric circuit to magnet M1. The pole of that magnet loses its magnetism instantly and rod R1 falls vertically. Similarly when the target is struck the magnet M2 releases the short rod R2 which falls and operates the trigger T and the knife K. The knife flies forward and makes a cut in the zinc jacket on the still falling rod R1, which cut is towards the upper end of the rod. The distance between the zero cut and this last cut, measured with a special rule, is the distance that rod R1 falls between the breaking of the first circuit at the muzzle and the breaking of the second circuit at the target. This distance, referred to a table, gives the time of flight in feet per second, from the muzzle wire to the target.

In taking velocities of rifle and pistol bullets it is the general practice in the United States to place the thin wire three feet in front of the gun muzzle, and the target at either 100 or 150 feet in front of the thin wire. The distance from the muzzle to midway between these two points is then either 53 or 78 feet. Therefore the instrumental velocity is usually recorded as (so many) foot seconds velocity at 53 feet or 78 feet. The distance between the two cuts on the recording rod R1 being referred to a table which gives the corresponding instrumental velocity at the selected distance. The muzzle velocity, if desired, can then be figured back from the instrumental velocity at 53 or 78 feet.

Shotgun shells are tested for velocity in a similar manner, usually over a 40 yard range, except skeet and .410 gauge shells which are tested over 25 and 30 yard ranges respectively.

It is the practice in the United States to fire five or ten shots for velocity, and to record the average as the mean velocity. The maximum and minimum velocities for the series may also be recorded. With first rate weapons and ammunition the variation in velocity, that is the difference between max and min, should not exceed fifteen feet. Too great variation, of course, results in vertical dispersion at the target.

There will be considerable variation between velocities taken with the same ammunition, but with different weapons. Two rifles, one with a tight bore, and one with a loose bore, or with different types of rifling, may vary as much as fifty feet per second in the instrumental velocity they give. This shows the uselessness of trying to figure too closely in selecting ammunition according to its velocity. Two cartridges, differing in advertised velocity by 25 or 50 f.s., might

actually be reversed in their performance in two given weapons.

Two lots of the same ammunition that is made on different days and loaded with different lots of powder, cases, and bullets, may also differ slightly in velocity, but manufacturers control the loading of different lots with pressure gun and chronograph so as to give very nearly identical performance. In such production tests pressure and velocity guns always have standard bores and standard length of barrels. An effort is also made to conduct these tests at a standard air temperature, usually 70 degrees F. In these days of controlled loading and guns and ammunition made on precision machines the uniformity of performance is truly astonishing.

The Aberdeen Chronograph

The Aberdeen chronograph was developed by the Ordnance Department of the Army at Aberdeen Proving Ground, Maryland. Like the Le Boulenge it records the velocity of the bullet between two electric circuits placed at a known distance apart, but with this instrument the circuits are "made" instead of "broken" by the bullet when it passes through the two screens. Each screen consists of two sheets of tin foil separated by a sheet of insulating paper. As the metal bullet passes through the screens it makes an instantaneous contact between the two sheets of tin foil which are wired into the electric circuit. Each circuit is wired through a spark coil to a spark plug which emits a spark at the very instant the bullet passes through the screen.

The Aberdeen chronograph consists of an electric motor of constant speed and known r.p.m. Its shaft carries a flanged disc arranged so that a strip of recording paper will ride on the inside periphery of the flange, being held tightly in place by centrifugal force as the drum revolves at high speed. The spark plugs are very close to this paper, and on firing each spark in turn burns a minute hole through the paper. The paper is of course revolving very fast on the drum, and the distance between the two spark holes gives the data by which we can determine the time between the penetration of the two screens by the bullet.

The Aberdeen chronograph has the advantage that it can be set up anywhere that electric current will reach, as the instrument is easily portable and no work bench is necessary. Also screens are easily set up anywhere, and as many screens as desired can be set up at varying points in the path of the bullet thus permitting the determination of velocities at different distances, as well as remaining velocities. By means of striker and muzzle actuated contact points it is also possible to record the barrel time.

In the absence of a chronograph the velocity of a bullet can be determined with a fair degree of accuracy by means of a trajectory

test, as described further in this work. If a bullet gives a trajectory identical with that of a cartridge whose trajectory is known, obviously its velocity over that distance is the same as the velocity of the bullet fired from the known cartridge over that distance.

New Methods and Equipment

The relatively simple methods of determining pressure and velocity described in the preceding pages are now regarded as rather obsolete by the larger ammunition companies. In general, electronic equipment is rapidly displacing the older mechanical types. Modern chronoscopes record more accurately, and measure more minute intervals of time than the older chronographs, and disjunctors of the coil and photo-electric type provide far greater precision than the older types such as muzzle wires, gate targets, and ball and spring type disjunctors. Some of these new instruments are shown and briefly described in Figures 19, 20, 21, and 22. Their use requires highly trained personnel.

CHAPTER III

Recoil, Jump, and Vibration

ONE of the effects of firing a cartridge in a small arm is to cause certain movements in the arm. These movements can be divided into recoil, jump, and vibration. A portion of these movements take place while the bullet or shot charge is still in the gun, affect the shooting of the gun, and are therefore included within the province of interior ballistics. Other portions do not occur until after the bullet has left the muzzle, and therefore only have a physical and psychological effect on the shooter.

That portion of the movement of the gun which occurs after the bullet leaves the bore, chiefly recoil, is not, strictly speaking, in order for discussion here, but its effect on the firer is so important that it would be well to treat it briefly before proceeding further. Roughly, recoil may be divided into two parts; first that which occurs while the projectile is still in the bore, which is relatively small in amount; and second the much more violent backward impulse occurring just after the bullet leaves the muzzle when the pent up gases rush out of the muzzle and act against the gun, resulting in the gun being thrown back violently, just as water coming out of a garden sprinkler makes it turn. The shooter cannot differentiate between these two portions of recoil, but with a gun that fires a cartridge of any considerable power he certainly is aware of their combined effect. This combined recoil that affects the shooter we will call

Appreciable Recoil

The effect on the shooter is a more or less severe blow or quick push on his shoulder, and perhaps on his face and jaw. With a hand gun the recoil falls mainly on the hand and wrist. The report or noise of the gun occurs at the same time, and where either or both are considerable they have a decided physical affect that is very detrimental to the marksmanship of the novice who has not steeled himself to disregard them. The beginner at shooting more or less dreads the recoil and report, and in order to get them over as soon

as possible he jerks the trigger, and perhaps he also shuts his eyes, and the shot strikes wide of the mark. Once the beginner has developed a tendency to jerk and flinch, and it can be developed in just a few shots, it is extremely difficult to break him of the habit. The shooting coach always finds it very much easier to teach a man to shoot well who has never fired a gun before, than to instruct one who has done a lot of undirected shooting. The latter has almost always developed the habit of flinching, and that habit has to be broken before any progress can be made. It is the most serious handicap to be overcome in teaching marksmanship.

The best and approved method of teaching a man or boy to shoot is to start him in with the .22 caliber small bore rifle which does not have any appreciable recoil. With it he is taught holding, aiming, trigger squeeze, sight adjustment, and all the details of good marksmanship, and he is then required to shoot scores for record, and perhaps to engage in informal competitions. It does not take long to acquire a considerable degree of skill in small bore rifle shooting, particularly under the eye of a competent coach. Certain individuals can even teach themselves with the aid of a proper manual. Every effort is made to develop the novice into an enthusiastic shooter, and to get him deeply interested in the game. If we then give this man a rifle, shotgun, or pistol having considerable but not excessive recoil, and he fires his first shot with it, he invariably makes some such remark as "Hell, that's nothing!" and proceeds to shoot equally well with the heavier weapon.

The amount of recoil that any individual with such training can stand without detrimental effect on his marksmanship depends on his temperament (nervous or phlegmatic), physique, weight, physical condition, and the susceptibility of his skin to bruising. *A great deal also depends upon the desire of the individual to shoot well.* We have seen many small, light women who were most excellent shots with the Springfield Model 1903 rifle which has a fairly heavy recoil. The late Mrs. Edward C. Crossman was probably the best woman shot in the world with the service rifle. Mrs. Martin (Osa) Johnson, a small and light woman, is a most excellent and cool shot with heavy recoiling elephant rifles. Hundreds of women have shot well up to the top in competitions with shotguns, which have greater recoil than our service rifle.

Recoil is measured in two ways; by its velocity and by its energy. The energy and velocity of recoil depend on the weight and velocity of the bullet and powder charge, and on the weight of the gun. But appreciable recoil also depends on the shape, dimensions, and fit of the butt-stock, and on the materials of which the butt-plate is made. To some extent it also depends upon the clothing that the shooter wears.

At the beginning of serious, studied shooting, British ballisticians, shooting instructors, and gunsmiths probably had more experience in this matter of appreciable recoil than anyone else because between about 1870 and 1910 they instructed so many men, boys, and women to shoot well with the shotgun. They gradually came to the conclusion that an average man or woman in good physical condition could not shoot any considerable number of shots in an afternoon without serious effect on physical condition (usually headache or bruising) with a shoulder gun that gave a greater recoil velocity than 15.4 feet per second in a 6½ pound gun. This is about the recoil of a 6½ pound shotgun with a standard 12 gauge field load, or of a 7½ pound gun with a 12 gauge high velocity load. The energies of these recoils will run about 24 to 26 foot pounds.

There is considerable difference, however, between the effect of recoil on the person when shooting a shotgun and a rifle. With the shotgun one shoots in an easy standing position, does not hold hard against the recoil which easily pushes his shoulder backwards, and his thoughts are concentrated much more on the moving target than on the gun. The rifleman, on the other hand, concentrates more on his weapon and for a longer time, dwelling on his hold, his aiming, and his trigger squeeze, and he may fire in the prone or sitting positions where his shoulder does not give so much to the recoil. He concentrates more on his rifle and on his technique of shooting than on his target, which to him is only something that will record where he hits. This is why the rifle shooter feels the recoil much less when shooting at game than at a target. His thoughts are then concentrated more on the game than on the gun. Therefore we find that as a rule individuals can withstand less recoil in target shooting with a rifle than with a shotgun.

In the matter of recoil with rifles we have had a great deal of experience in our army. The energy of recoil of our old .45-70 Springfield rifle shooting the black powder cartridge with 500 grain bullet was 18.4 foot pounds. This recoil was quite severe, many bruised shoulders and headaches occurred, and often we had trouble in developing men into good marksmen. With the .30-40 Krag Jorgensen rifle which the army used from 1896 to 1906 the recoil was much lighter, only about 11.5 foot pounds, and was hardly a factor in marksmanship instruction. With the .30 caliber Springfield Model 1903 rifle the recoil with the 1906 cartridge was slightly greater, being about 14 foot pounds, and while the difficulties of marksmanship instruction due to recoil were a little greater than with the Krag, they were not really serious. But with the adoption of the M1 cartridge (172 grain bullet at M.V. 2640 f.s.) recoil became a little more of a problem. The recent M2 cartridge gives enough reduction in recoil as compared with the M1 to make the work of rifle instruc-

tors much easier. We may therefore place the rifle recoil that the average individual can stand for an afternoon's shooting without affecting his marksmanship as about 14 foot pounds, or only a little more than half that of average shotgun recoil. Of course, as already explained, individuals differ, and some can stand much more recoil than others.

The shape and dimensions of the butt-stock also have a great deal to do with the effect of the recoil. With a large, heavy stock, with comparatively little drop at the heel, and with a large flat "shotgun" butt-plate, a shooter can stand more recoil than with the miserable little stocks that used to be fitted to many American rifles and shotguns some years ago. A short stock appears to increase the recoil, and also a stock with a low comb that requires light or almost no cheek pressure is liable to rise up and give one a disagreeable jab in the jaw and cheek. When the Remington Model 30 bolt action rifle was first produced it was fitted with the old fashioned American crescent shaped butt-plate. The writer, who can stand much more recoil than most men, found the recoil of this rifle with this stock most disagreeable, even with so light a cartridge as the .25 Remington. It was almost impossible to fire many shots in the prone position with our old heavy caliber black powder rifles that had crescent shaped butt-plates. The long stocks with large, flat butt-plates that have invariably been fitted to British shotguns and rifles for the past one hundred and fifty years do much to minimize the effect of appreciable recoil. A soft rubber butt-plate or recoil pad is a good thing on a gun having heavy recoil. Generally speaking the butt-plate should never be shorter than 5⅛ inches, nor narrower than 1⅝ inches. Some revolvers have the upper rear portion of the grip, just in rear of the hammer raised and set back to such an extent that it usually very seriously bruises the hand in the web between the thumb and first finger, which induces flinching. Some shotgun shooters find themselves flinching when firing the left barrel, from the front trigger badly bruising their finger when it releases the real trigger.

Calculation of Recoil

It is comparatively easy to calculate the total recoil of a shotgun or rifle. The "ejecta" is the combined weight of the powder and bullet, on in the case of a shotgun, the powder, shot charge, and wadding, which must be stated in pounds. To convert grains to pounds divide by 7,000. The formula is:

Ejecta (in pounds) $\times$ Velocity (f.s.) $=$ Momentum.
Momentum $\div$ weight of gun $=$ Velocity of recoil.
Velocity of recoil squared $\div$ 2g (64.32) $=$ energy of recoil.

Example: To find the recoil of a 6½ pound shotgun with 1¹⁄₁₆ ounces of shot, and a muzzle velocity of 1300 f.s.:

Weight of shot charge 1¹⁄₁₆ oz.	464 grains.
Weight of wadding	40 "
Weight of powder	33 "
Total weight of ejecta	537 "
537 grains ÷ 7,000	.767 pounds

.767 × muzzle velocity (1300 f.s.) = 99.73 Momentum
Momentum ÷ weight of gun (6.5 lbs) = 15.4 f.s. velocity
$15.4^2 \times 6.5 \div 64.32 = 24$ foot pounds

That is, the velocity of recoil is 15.4 f.s., and the energy of recoil is 24 foot pounds. The recoil with black powder will be greater than the above because the charge of black powder to give M.V. 1300 f.s. will weigh much more than the above charge of smokeless powder. Also the increased report of black powder, and the smoke have the psychological effect of making the recoil seem greater.

It is, however, very misleading to publish the recoil of a number of guns and loads, even when the weight of the gun is given, because of the very great influence that the design of the stock has on recoil. For example, the recoil of the .45-90 Winchester Model 1886 rifle was 11.38 foot pounds with smokeless powder, and 16.53 foot pounds with black powder, but that old rifle was almost invariably fitted with a short, low combed stock with the old crescent shaped butt-plate, and its recoil when fired in the prone position, or in a well braced sitting position was about as disagreeable as one could imagine.

Initial Recoil

(Before the bullet leaves the muzzle)

When the powder in the cartridge burns it exerts pressure in all directions, and not on the bullet base alone. It presses on the base of the bullet and drives the bullet forward. It presses equally on the sides of the cartridge case until that pressure is stopped by the chamber walls. And it presses on the base of the cartridge case, and thence against the bolt or breech block, and drives the gun backward. It drives the gun to the rear with the same energy that it drives the bullet forward, but at a velocity that is proportionate to the weight of the bullet and the gun. If the gun weighs one hundred times as much as the bullet, and the bullet's velocity is 2000 f.s., then the velocity of recoil of the gun will be 20 f.s. This is not absolutely correct because we must add to the weight of the bullet the weight of the column of air in the bore ahead of the bullet, the friction the bullet encounters in the bore, and the weight of the shooter's shoul-

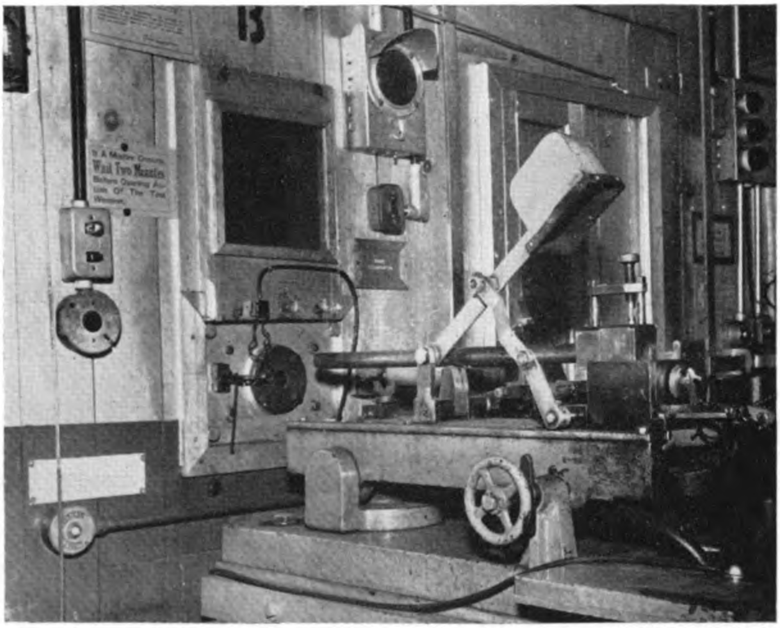


FIGURE 7

Shotshell pressure gauge in position for loading, showing heavy barrel and breech mechanism, with arbor, set screw, anvil, and crusher cylinder in place. When the shell is placed in the chamber the safety guard above is pulled down over the breech, depressing the barrel and action, and moving them forward so that the muzzle projects through the firing port as shown in Figure 8. Courtesy of Remington Arms Co.

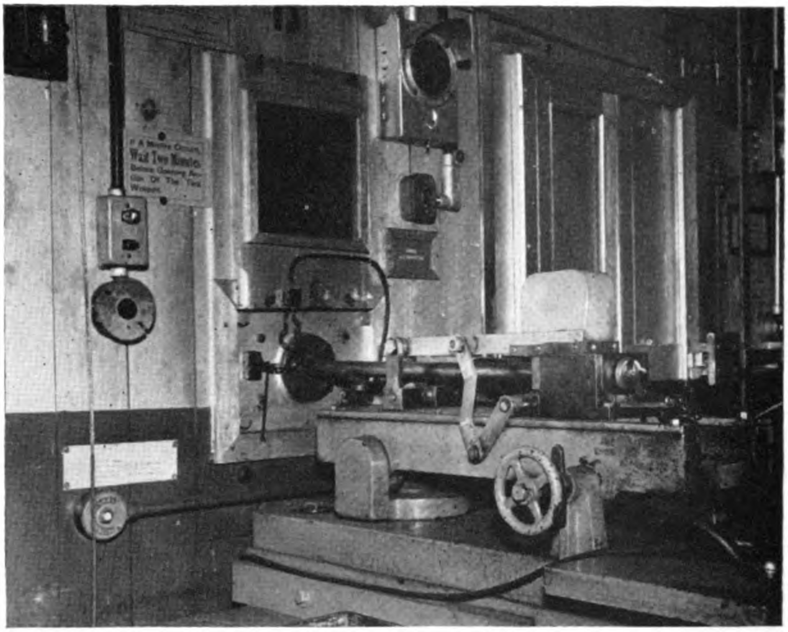


FIGURE 8

Shotshell pressure gauge in firing position, showing safety guard pulled down, and muzzle projecting through firing port. The wall or partition in front of the gauge separates the firing points from the range proper, the door not opening until all the guns have been cleared. The reverse side of this partition is heavily padded with felt to deaden the noise.

der pressure against the butt-plate. The first two factors are small, and the latter very variable, so we disregard them in calculating recoil. But nevertheless the recoil of the gun is very fast, and the only thing that lets us bear it is the extremely short interval of time over which it occurs. During this recoil the gun moves a very small fraction of an inch.

Jump

In what direction does the gun move before the bullet leaves the muzzle? It would seem that the barrel and gun would move straight to the rear, but this is not true with a normally constructed gun that is fired from the shoulder, or with a pistol that is fired from the hand. The force (pressure) that pushes the gun backward operates above the center of gravity of the gun which thus tends to rotate around the horizontal axis through the center of gravity, so that the barrel moves both backward and *upward* before the bullet leaves the muzzle. Also the shoulder pressure on the butt-plate which restricts the movement is considerably below the axis of the bore, and this still further operates to cause the barrel to move upward against and around the shoulder resistance. To be more correct let us say that the breech, or rear end of the barrel moves both backward and upward. This movement is termed the *jump*. Therefore the bullet does not leave the muzzle in prolongation of the axis of the bore as the bore is at the instant before firing, but rather in prolongation of the line that the axis is forced into by the jump. Thus when we finally adjust the sights of the gun with precision we adjust them to the striking point of the bullet on the target which is the prolongation of the axis of the bore as determined by the jump plus the gravity fall of the bullet over the distance. But this is not all of jump—we will come to it again below.

Vibration

The third movement of the gun before the bullet leaves the bore is termed *vibration*. When the trigger of the gun is pressed, the fall of the firing pin and the blow of the striker on the primer set up certain more or less small vibrations in the weapon. But these small vibrations are almost instantly blotted out by the very powerful jump of the whole gun caused by the discharge of the cartridge. Other much more extensive vibrations occur as a result of the jump. The barrel of a rifle or shotgun is not a rigid body incapable of bending, but on the other hand is very sensitive to stress. If a fairly light (thin) barrel be secured in a vise at the breech, and the remainder be free, it can be bent appreciably by finger pressure applied at the muzzle end. If the pressure be not too heavy the barrel will spring back to its original straight form when the pressure is re-

lieved. Similarly, medium and heavy weight barrels may be bent by more or less heavy hand pressure. These bends can be seen clearly with a specially constructed telescope inserted in the bore. Like any other metal rod, a gun barrel vibrates when struck or subjected to a sudden stress, such as the firing of a cartridge in it. It is with the vibrations of a rod rigidly fixed at one end that we are here concerned. English ballisticians who have perhaps investigated barrel vibrations more than we have, state; "There are two types of transverse vibrations which can be set up. (1) A fundamental vibration in which the whole length of the barrel vibrates as a single unit, there being only one node or point at which the barrel is still, the point at which it is fixed (breech). (2) A series of overtones in which the barrel is divided longitudinally into a number of vibrating sections, each terminating in a node at the end nearer the breech. These two types of vibrations can and do co-exist. The frequency of the fundamental vibrations depends upon the proportions of the barrel, and that of each particular overtone is always a fixed ratio to that of the fundamental. The shock of the explosion naturally sets up these vibrations in a violent form, and they are affected in a greater degree by irregularities in the shape of the barrel, by external attachments, and by the manner in which it is stocked up. The compounded effect of the fundamental vibration and the overtones, at the moment when the bullet quits the muzzle, on the inclination of the last few inches of the barrel in relation to the axis of the bore before firing, *constitute the main contributing factor in the "jump" of the rifle."*—British "Text Book of Small Arms, 1929." (The writer does not agree with the words in italics except in the case of the S.M.L.E. rifle, which was the weapon under chief consideration in the above quotation.)

Other vibrations may also occur from other causes such as the manner of support of the face of the breech block, and the friction of the bullet in the bore. If the face of the breech block or bolt be not uniformly supported at both sides the vibrations may have a lateral as well as vertical motion. Thus with the Caliber .30 Krag Jorgensen rifle there is a deviation to the left from what would be the normal plane of fire, due to jump plus vibration, of at least 2.5 minutes, which is not negatived by the drift until the bullet has reached about 1,100 yards. The Krag has but one locking lug at the head and bottom of the bolt.

Bullets of varying velocity will depart from the muzzle at varying points in the jump-vibration, and hence will strike the target at varying points, even at short distances where the trajectory would make no appreciable difference. Thus at 100 yards it is quite a common thing to have a reduced load with a velocity of about half the full charge strike the target at from 3 to 9 inches below where the

full charge strikes with the same sight setting, where the trajectory would only account for a drop of 2 inches or less, and this reduced load may also strike an inch or two to the right or left of a plane through the full charged center of impact. We also often find certain rifles with such a peculiar jump-vibration that the reduced load actually strikes higher on the target than the full charge. It is thus impossible to estimate velocity or trajectory of two cartridges from relative location of center of impact unless we zero each at some very short range such as 12½ yards, and figure the elevation and drop of the bullet from the zero of that load.

Jump Plus or Minus Vibration

Thus the barrel vibrates while, or rather after it jumps, and the compound sum of the two determine the alinement of the last few inches of the bore at the instant that the bullet leaves the muzzle. So far we have been unable to tell how much of this movement is due to jump and how much to vibration. For simplicity, the ballistician therefore refers to the whole movement of the barrel as "jump."

We now come to the really important effect of this recoil-jump-vibration movement that occurs before the bullet leaves the muzzle. That is the manner in which it affects the practical shooting of the rifle, pistol, or revolver. This movement is very considerably affected or modified by the manner in which the weapon is held or rested, by gunsling tension, and by stock pressure. If we are to predict the accuracy of our weapon, the spot where the bullet will strike the target with respect to the line of aim, the location of the center of impact; if our ballistic experiments are to be free from errors that would totally destroy their value; we must eliminate all the exterior factors which effect jump.

It is desirable that we here set forth at considerable length some of these exterior factors which affect the jump.

Resting the Rifle

The Effect of the Firing Position. It has long been known that resting the barrel or the forearm of a rifle on a solid substance, such as a board, a log, or a rock, causes the bullet to strike higher on the target than if the rifle were held by the hands alone. The harder the substance on which the barrel is rested, the higher will the bullet strike on the target, and also the closer the rest is to the muzzle the higher will it strike. A heavy barrel is less affected in this manner than a light one. All this has been demonstrated in hundreds of experiments. It is believed that it is correct to state that a barrel when rested is restricted from jumping down so much at the muzzle, or

that the rest causes it to jump upward more, whichever way the student prefers to state it. The effect is the same.

Furthermore, *all* of the writer's shooting for many years has indicated that when the rifle is fired from a bench rest, the center of the forearm being laid on a rest cushioned with sponge rubber a half inch thick, and the butt-plate supported on the shoulder, the location of the center of impact is the same as when the rifle is supported and held by the hands, cheek, and shoulder alone. Very steady firing, sufficient for almost any ballistic experiment, can be done in this manner after a little practice.

A similar effect to resting the rifle on a hard substance, but in a different direction, is caused by the heavy tension of a shooting gunsling on which a trained rifleman, shooting in the prone position, may place a pull of from 25 to 50 pounds. The pull down on the barrel restricts the upward jump, or increases the downward jump, or it may even bend the barrel. The result is that the bullet strikes lower on the target than it would if held by the hands alone, or if fired from a cushioned forearm rest. Riflemen have reported a great many times that when shooting in the prone position with the gunsling at 100 yards the bullets strike the target from one to five inches lower than when they shoot offhand. There have been very few reports where there was no effect, and these have been confined to full floating heavy barrels. There have been no reports in the opposite direction. The difference, as might be supposed, is greater with a light than with a heavy barrel, and is greater when the gunsling is attached to the barrel than when it is attached to the forearm alone.

The writer has in late years conducted such experiments to determine the effect of the gunsling with almost every rifle he owns because for successful field shooting the effect of the firing position on the shooting is vital. The rifles were first shot from bench rest, the center of the forearm being rested on a sponge rubber pad as described, and the location of the center of impact was then established. Immediately the writer lay down on the prone firing point, which was alongside the bench rest, assumed the standard military prone position with the gunsling, and fired in that position with the same sight adjustment and aim, and established the center of impact for that position. The average variation with different rifles has been from one to five inches. The variation with any one rifle when tried repeatedly has been as much as two inches between maximum and minimum variations.

The reason why the same rifle did not always vary the same from padded rest to prone gunsling was because the firing positions were not always the same. The cushioned bench rest position was probably the same or nearly the same each time because many repeated experiments in this position alone have shown almost no variation

in center of impact. But it is practically impossible to assume the prone position the same each time as the position will vary a little, the general tension of the whole position, the tension on the gunsling, and the spot on the ground where the elbows rest. In successive shootings in the prone position, getting up from the firing point between scores, and assuming the position afresh, the location of the center of impact often varies as much as 1½ minutes, despite the fact that from forty years practice in this position the writer assumes it in a very uniform manner.

Thus in shooting the same rifle from bench rest and prone with gunsling, the difference has varied from nothing to about five minutes. That is, one rifle may show variations of from nothing to two inches at 100 yards, and another from three to five inches. All of these variations are due to a variation in jump. Two inches at 100 yards means four inches at 200 yards—enough to miss a man's head. Two inches at 100 yards means six inches at 300 yards—enough to miss the vital part on a deer's body. For success in practical field shooting the rifleman must know how his firing position will affect the shooting of his rifle, and make allowances accordingly. And the ballistician must take these matters into consideration in his experiments.

It is the practice in the United States Army to start recruits firing in the prone position with sandbag rest in order that they will be able to hold the rifle steadily at the start, and thus be able to concentrate all their attention on the trigger squeeze. In this position the normal prone position is assumed, and the gunsling is used, *but the left hand is rested on the sandbag* which steadies the position. The writer has conducted a number of tests with the Springfield 1903 service rifle to determine the effect of shooting in the sandbag rest position and in the normal prone position with the gunsling. Sometimes the rifle would shoot a little higher, and again a little lower in one position than in the other, because neither position could be assumed with identical tension each time the comparative tests were made. Averaging up did not show any difference in the location of the center of impact in either position, even when the test was extended to 600 yards, because in both positions the gunsling is used and its pull down averages the same. In the rest position the rifle rests on the hand and not on the sandbag, and the hand makes a well padded rest which has little or no effect. Both positions are practically the same so far as the tension on the rifle is concerned.

But it is a different matter when we come to resting the rifle directly on the sandbag without the hand intervening and without using the gunsling. If we are shooting a sporting type rifle with short forearm in contact with the barrel the shots fired from the sandbag

rest will strike the target much higher than those fired with the gunsling in the prone position for the reasons given above. However, when the Springfield 1903 service rifle is used the effect of resting and holding is rather unpredictable because the barrel is, or is intended to be, free floating within its forestock and hand-guard. It may be so, or there may be more contact of wood to barrel in varying spots than was intended, or the tension of the gunsling may bring either forestock or hand-guard to bear heavily on the barrel.

In competitive small bore rifle shooting the shooter is permitted a number of fouling and sighting shots before he starts his record shooting, and a target is provided for that purpose. For example, in a 20-shot match at 100 yards the time limit is twenty minutes—five minutes for fouling and sighting shots, and fifteen minutes for the twenty record shots. The target has three bullseyes, one above the other. The fouling and sighting shots are fired on the top bullseye. The time limit having started, the competitor fires three or four shots rapidly from his rifle, usually aiming them into the butt, to foul and warm his rifle, because a rifle shooting the .22 Long Rifle cartridge does not shoot consistently until the bore has been fouled and warmed. Then he proceeds to fire sighting shots on the top sighting bullseye, and he makes any needed alterations in his sight adjustment until his bullets are striking consistently in the 10-ring in the center of the bullseye—because he cannot surely predict the correct sight adjustment in advance for he does not know how the particular prone position he assumes and his tension of holding is going to affect the jump of his rifle, and consequently where the bullets will strike the target.

Having settled down into a uniform position, and with his bullets striking in the ten ring, he then turns on the middle bullseye and starts shooting for record. Now if he is a skilled and experienced shooter he takes great pains to assume precisely the same position for each shot. Particularly does he keep his left elbow resting on the same spot on the ground, never raising it, and he maintains the same adjustment and tension on the gunsling for every shot, never changing the gunsling's position on the arm. He knows from long experience that if he takes his left elbow off the ground, or alters sling tension, that his next shot will almost certainly strike out of the ten-ring, because the very slight change in firing position has altered the jump of his rifle.

The writer has had an experience of this nature that for four consecutive years has remained unchanged. In order to keep in training it has been his practice during the summer months to fire at least a string of forty shots prone at 100 yards almost every day from his small bore match rifle. This rifle, a Remington Model 37, has the usual heavy, full floating barrel. On week days he fires on his own

private range. On Sundays he goes to the range of a neighboring rifle club for competitions. On his own rifle range there are elbow holes well worn in the sod, and he is familiar with the lie of the ground, so that from day to day he assumes almost an identical position. On this range his correct elevations have varied very little, seldom as much as three-fourths of a minute. Also the target at 100 yards is about six feet below the level of the firing point. On the club range, however, the firing point is covered with short clipped sod without elbow holes, and the targets are on the same level as the firing point. Invariably on this club range he has to use a lower sight elevation, lower by 1½ to 2½ minutes than on his home range because his tension of holding is different, and this affects the jump of the rifle.

If we would hit our enemy, our game, or the bullseye with the first shot we must assume a uniform firing position with uniform tension—the same position as that in which we determined our sight adjustment. Or we must know how much any change in position will affect the location of the center of impact and make allowance for it in aiming. As an example, the writer has a big game rifle which in six years of most careful annual tests has not changed its zero. He knows that offhand it will shoot precisely where he aims at 200 yards, and that prone with the gunsling it will average shooting 4 inches lower, because he has verified this over six years trials.

Suppose one is conducting a simple ballistic experiment to determine the sight adjustment, angles of elevation, and trajectory at various distances with a certain rifle and cartridge. He shoots at 100 yards and determines the correct sight adjustment for that distance. Then *he gets up,* moves his target or his firing point back to 200 yards, and determines his sight adjustment there. Then *he gets up,* moves back to 100 yards and shoots at that distance with his 200 yard sight adjustment to determine the height of trajectory at 100 yards when shooting with sights adjusted for 200 yards. His results will probably be full of errors because each time he got out of position, and at the next shooting point assumed a slightly different position, with attendant differences in jump and location of center of impact. But if he had arranged his two targets, one at 100 and the other at 200 yards, one almost directly back of the other, but unmasking enough so that each could be aimed at and fired on without change in position, and then assumed one firing position and maintained it throughout the whole test, and finally in the last shooting firing alternate shots at each target, he would have far less error, and probably no error, and results that would be fairly reliable.

It is just such things as this that cast doubt on certain ballistic tests of some years ago on which certain principles we now begin to doubt have been based. For example, some years ago a very skilled

rifle shooter sighted his rifle in most carefully at his home at sea level. Then he journeyed three thousand miles and reached an elevation of 8,000 feet, where he again targeted his rifle, and found the bullet striking much higher. He did not state the temperature at the two tests. Was the difference due to altitude, or to a change in firing position? We suspect very strongly that it was due almost entirely to the latter cause. The writer now realizes that some of his tests of many years ago contained serious errors, and that the conclusions based on them were unsound. We live and learn.

Influence of Stock on Jump. The bedding of the rifle in its stock may have considerable influence on the jump. The breech action must be tightly and accurately bedded so that, even with the heavy blow of recoil, the receiver cannot drive back a particle in the stock, nor rock back and forth or from side to side. The guard or tang screws must be kept set up tight, and their security should be verified from time to time as all screws are liable to loosen from the vibration of firing.

Wood is never stable. It is always liable to swell, shrink, and warp, and no way has been found to prevent this, although keeping the surface pores of the wood well filled with boiled linseed oil will reduce the tendency, as will also guarding the stock from exposure, and drying it quickly when it gets wet. When such care is taken the writer would state that from his experience about three out of four rifles, where the stock has originally been perfectly bedded, no trouble will ever be experienced from swelling, shrinking, and warping—of course where well seasoned walnut has been used for the stock. But all too frequently a forearm, no matter how perfectly fitted, will change from exposure to damp or dry heat so as to place more or less pressure on the bottom or sides of the barrel and alter the jump. It is astonishing how just a little pressure of this kind will temporarily or permanently change the location of the center of impact or ruin the accuracy. This is no idle dream. The writer has seen it occur dozens and dozens of times. Two instances will suffice to illustrate.

Probably much more attention is devoted to the proper bedding of the excellent Winchester Model 70 bolt action rifle in its stock than with most rifles built in America. One summer a rifle of this model started to shoot very poorly, averaging an extreme spread of 3.60 inches at 100 yards. Without moving from the bench rest or getting out of position, an assistant loosened the forearm screw (which had previously been screwed up fairly tight) a half turn. This lowered the center of impact .75 inch and moved it to the right 1.00 inch at 100 yards, and reduced the extreme spread for ten shots to 2.52 inches. Then turning the screw out another half turn still further lowered the impact .75 inch and moved it .75 inch more to the

right, and the extreme spread shrank to 2.35 inches. The barrel and receiver were then taken out of the stock, and by applying mechanics blue to the barrel it was found that the forearm pressed harder on the left side of the barrel than on the right. The forearm groove was very slightly relieved on this side, and at the same time the forearm stud which is secured to the barrel boss by a dovetail slot, and into which the forearm screw enters, was eased up so that it would slide back and forth through its slot in the barrel boss by slight pressure of the fingers alone. This obviated any chance of the forearm screw and stud placing any side strain on the barrel. The rifle was then assembled, the forearm screw being screwed up fairly tight and then relieved a full turn. The rifle was then fired at 100 yards, and the ten shot group had an extreme spread of .95 inch, and the rifle has continued to shoot in a gilt edge manner ever since.

A .22-3000 Lovell 2R rifle with medium weight barrel in a Sharps Borchardt action shot very poorly. Groups at 100 yards ran as high as 6 inches. It was suggested that the forearm might be bearing too hard against the receiver, thus restricting the downward jump. This contact was relieved, and the forearm screwed back just fairly tight, and thereafter *all* the shooting done with this rifle at 100 yards has resulted in groups measuring 1.35; 1.2; 1.08; 1.48; 1.47; 1.00; .52; 1.70; 1.03; .79; 1.12, and .68 inches, average 1.12 inches. This originally extremely inaccurate weapon is now gilt edge.

In addition to the receiver being bedded and secured in the stock as above described, the writer feels that the barrels of all bolt action rifles, where not otherwise dictated by military necessity, should be "free floating" within their forearms. That is, the forearm should not touch the barrel anywhere, it being possible to pass a sheet of thin paper everywhere between the barrel and forearm. This almost always results in best accuracy and minimum change in center of impact due to different manners of resting and holding the rifle. The front sling swivel is screwed to the forearm only. Heavy tension on the sling does result in some strain being transmitted by the forearm to the receiver, but not nearly so much as when the forearm is fastened to the barrel. Thus the difference between offhand and prone positions is much less.

The Winchester Repeating Arms Company employ a unique and apparently very excellent method of bedding in their Model 52 small bore match rifles. At all prominent contact points between barrel, receiver, and stock, small, button like, synthetic rubber cushions are set into the wood, rising slightly above the surface of the wood. The barrel and receiver are screwed down into more or less tight contact with these cushions so that they are bedded entirely on soft rubber, with the exception of the recoil shoulder. The fact that almost invariably exceptionally fine accuracy is obtained with this rifle seems

to indicate that there is much merit to this method of bedding on rubber, at least with rifles taking light cartridges.

The remarks above apply more particularly to bolt action rifles with one-piece stocks. With rifles having a separate forearm all experience seems to indicate that there should be no tight pressure between the forearm and the receiver, that the forearm should be just a snug and perfect fit to the contour of the barrel, and should be secured to the barrel by only one screw located at the center of the forearm, this screw being turned up only fairly tight.

Jump is probably very variable, and the influence of holding or tension on it is unpredictable, with light and medium weight rifles having tubular magazines under the barrel, or with any rifle having a "takedown" barrel. No fine degree of accuracy is obtainable from such rifles, although in small and light calibers the accuracy is much better than with heavier cartridges. Fair accuracy is usually obtainable with lever and pump action rifles for the .22 Long Rifle, .218 Bee, .25-20 low power smokeless, and .32-40 low power smokeless cartridges, but in heavier calibers the dispersion usually exceeds three minutes and varies according to the manner of holding and the number of cartridges in the tubular magazine. With such rifles the dispersion apparently also increases as the rifle warms up from repeated firing, and the best accuracy is usually obtained by firing in strings of three shots, starting with the rifle cold. This is the manner in which such rifles are fired in hunting, and thus the practical hunting accuracy is probably much better than the firing of a 10-shot accuracy test would indicate.

Direction of Jump

In what direction is the vertical jump? Is it up or down with respect to the axis of the bore when the rifle is at rest? To many it seems as though it must be up because when a rifle is held with the butt to the shoulder, and with its center of gravity below the bore line, it recoils and rotates around the point of resistance (butt-plate) and thus the rifle rises or most decidedly seems to rise. Thus it has been thought that the bullet departs from the muzzle when the bore is pointed upward above the line it had at rest. But let us look into this a little more fully and we will discover some interesting things.

A light weight, long barrel such as those on our military and light weight sporting rifles is not a stiff rod or cylinder as might be supposed. It can be bent by pressure of fingers and thumbs alone. If not bent too much it will spring back to its original straightness as soon as the pressure is relieved. Medium weight barrels can be bent appreciably by heavy hand pressure, and heavy barrels by the pressure of the hands augmented by body weight. These bends can be seen with the aid of a special telescope inserted in the bore. The energy

of the pressures that will bend these barrels is very much less than the energy of the blow they receive when the cartridge is discharged.

As an illustration of what may happen let us take something that is easily bent—a fishing rod. If we hold a fly-rod by its grip, rod horizontal, then suddenly give it a strong upward and backward flip or impulse with our hand on the grip, the grip and the section nearest our hand will rise upward and backward. But the whole rod bends, and the tip section actually bends *downward* before it starts to rise, and this down bend is clearly apparent to anyone. The barrel of a rifle that is free to recoil without abnormally restraining influences, does exactly the same thing when fired from the shoulder. It is the direction of the last few inches of the bore that determines the angle of departure of the bullet. If these last few inches of the bore be bent downward (as in the case of the fly-rod), then when the bullet leaves the bore it will depart at a downward angle with respect to the alinement of the bore when the trigger was pressed. The bullet will therefore strike the target below the line of prolongation of the bore at rest, and below what it would have dropped over the range from gravity. If, however, the muzzle portion of the barrel had time to vibrate upward after its initial jump downward, then the bullet may strike above the prolongation of the bore at rest.

There is considerable literature on this matter, but as most of it is now buried where it is not easily accessible, I take the liberty of making several quotations.

The first reference is contained in a letter from Mr. W. E. Metford, the leading British small arms ballistician of his day to Mr. J. H. Walsh, editor of the London Field, and contained in the book "The Modern Sportsman's Gun and Rifle," 1884:

"When I began scientific rifle work—now, I am sorry to say, over thirty years since—I felt that the proper thing to do would be to rig up a telescope sight, and that it would also be a proper thing to put its optical axis (in which line the cross-wires lay) absolutely parallel with the axis of the bore. This I did with all the caution and skill I was master of (I was at that time able to make a theodolite, bar the dividing and the optical glass work). With my telescope set to zero (or parallel with bore axis) I went to shoot at 25 yards, speed 1,400 feet, therefore drop of bullet at 25 yards a trifle over ½-inch. Telescope was 1 inch above bar axis, therefore I expected the bullet to strike 1½ inches under the center of spot (rifle not rested). Nothing of the sort happened; the bullet struck a considerable distance under. I at once thought I had made some stupid blunder, and reset the whole work again, but still the rifle did the same * * * The point is, What is the cause?

"My friend William Froude solved it, and showed clearly that it was

entirely due to the mass of the stock being unsymmetrical with the mass of the barrel; and the first thing the barrel would do on explosion would be that the muzzle would flip down, the barrel bending in a curve (this flip down would be dependent for its amount and velocity on the masses, and length, and stiffness, and charge of powder, etc.); and that eventually the whole motion would reverse itself, and the whole gun kick up; but that the bullet would be gone before the barrel had returned to its level and above it, unless the barrel was very stiff and short."

Next let us see what our old reliable H. M. Pope has to say on the matter, quoted from his article in ARMS AND THE MAN of March 5, 1914:

"The action of the recoil is straight back in line with the barrel, but the resistance is always below the line of the barrel; that is the center of gravity of the rifle, also the resistance of the shoulder. This low resistance causes the whole gun to try to revolve around the center of resistance, precisely as pressure on the crank of a bicycle wheel tends to revolve the wheel.

"This sudden pressure bends the gun in a curve, with the center below the barrel, and causes the muzzle to dip and the breech to rise out of line and shoot low."

Lastly we quote from Major Gerald Burrard, D.S.O., R.F.A., at present the leading British writer on small arms ballistics—from his book "In the Gunroom." 1930:

"In rifles and shotguns there are really two elements of jump which should be distinguished. These are: (1) The weapon moves as a whole about the point of the stock where the recoil is taken and gives a positive jump; and (2) the barrel bends or flips during the same interval of time in which the first mentioned movement of positive jump is taking place. The second of these two elements is much the more important, as it exercises the controlling factor on the total movement of the weapon during the shock of firing, and consequently in sporting and military small arms gunnery the term flip is invariably used in place of jump and is regarded to include both elements.

"The flip of a barrel consists partly of a bending, just as a fishing rod bends when the angler strikes, and partly of a vibrating set up in the barrel by the movement of the cartridge case and breech fittings under the sudden application of the powder pressure. The bending of the barrel during recoil is always negative, because the barrel becomes the arc of a circle and the axis near the muzzle has a direction downward in regard to its original position, just as the point of a fishing rod assumes a more downward direction when the angler strikes. But the effect of barrel vibrations may be either positive or negative according

to the time the bullet takes to travel up the bore, and whether the bullet leaves the muzzle at the top or bottom of a vibration. Actually the resultant flip is the sum of these two effects.

"Flip varies with every barrel and action, and even with the same barrel and action when they are bedded differently in the stock. It is dependent on the length and thickness of the barrel; the method of support which the barrel receives; the rigidity of the attachment of the barrel to the action, as well as the action itself; and the tightness of the bearing between the action and the stock.

"In actual practice the flip is counteracted by the sighting of the weapon."

The writer has conducted a few experiments of his own to endeavor to determine the direction of the jump, and the angle of departure relative to the axis of the bore at rest. Various rifles in his collection that were equipped with telescope sights having double micrometer, quarter minute click mountings, and adjustable below the zero elevation, were employed.

The distance from the axis of the bore to the center of the telescope tube was measured with a micrometer. This distance was laid off on the target. At the point representing the axis of the bore a 1-inch black bullseye was drawn, and above it at the point representing the height of sight a black aiming circle was similarly drawn. This target was set up at a distance of 12½ yards from the muzzle of the rifle. The rifle was placed on the bench rest, and its bore was alined on the black bullseye, using a fired case with peep hole through the flash hole to perfect this alinement. While so held the telescope was then adjusted so that its cross-hairs intersected in the black circle. The line of bore axis and line of aim were thus made parallel or approximately so.

The rifle was then held on the bench rest, butt of the rifle resting against the shoulder, the forearm directly under the chamber resting on a sponge rubber pad one-half inch thick. A practically errorless aim and squeeze could be obtained in this manner. The rifle was then fired several shots to foul and warm the bore then a shot was fired at the target, aiming the telescope on the black circle. The bullet hole then showed if the jump was negative below the center of the black bullseye, or positive above it. Of course the fall from gravity over the 12½ yards had to be considered.

The whole procedure and calibration from the start were then repeated, and a second shot was fired for verification and check. The various targets and the two bullet holes are shown in Figure 23 A, B, C, and D.

A. Shot with a Winchester Model 70 Standard Rifle, 24-inch barrel, which had been relined by Diller and chambered by Gebby for

the .22-3000 Lovell 2R cartridge, 16-inch twist, groove diameter .2235-inch. Lyman 8 power Junior Targetspot scope. The load was the 50 grain Sisk Lovell bullet, 17 grains du Pont No. 4198 powder, and Winchester No. 116 primer, M.V. approximately 3000 f.s. The first shot struck .48-inch, and the second shot .50-inch below the bore line, seemingly showing that the muzzle jumped down, and that upward vibration did not occur to any extent before the bullet left the bore. Note the high velocity of this cartridge and hence short barrel time.

B. Shot with a Springfield Model 1922 Rifle which had been rechambered by Colonel Woody for the .22 Hornet cartridge. Twist 16-inches, groove diameter .2235-inch. This rifle had the standard Springfield sporting (.22 cal.) stock and band around barrel and forearm, and was bedded in the standard manner so that the forearm tip pressed upward rather hard on the bottom of the barrel. Fecker 4 power Small Game Scope. Winchester 1932 factory cartridge, 45 grain soft point bullet, M.V. 2425 f.s. The first shot struck .22-inch, and the second shot .07-inch above the bore line. Possibly the upward pressure of the forearm tip on the barrel minimized the down jump, and the rather slower barrel time as compared with A above permitted some upward vibration to occur before the bullet left the bore.

C. Shot with a Remington Model 37 Match Rifle, floating barrel. Lyman 20 power Super Targetspot Scope. Remington Kleanbore .22 Long Rifle cartridge, M.V. about 1100 f.s. The first shot struck .42-inch, and the second .27-inch above the bore line. With this low velocity cartridge approximately .15-inch should be added to each of the above figures for the gravity drop of the bullet. Presumably the barrel time is so long that there is time for some upward vibration to occur before the bullet leaves the bore.

D. Shot with a Winchester Single Shot Rifle for the .30-40 Krag cartridge. 27-inch No. 3 barrel, 10-inch twist, groove diameter .308-inch. Two piece stock and usual short forearm secured to the barrel by one screw. Fecker 4 power Small Game Scope. Remington factory cartridge, 180 grain bronze point bullet, M.V. in this 27-inch barrel about 2400 f.s. The first shot struck .04-inch below, and the second shot .26-inch above the bore line. The reader can figure the jump and vibration as he wishes.

Lee Enfield (S.M.L.E.) Rifle. "The British Text Book of Small Arms, 1929," states that the jump (jump + vibration) is between 4 and 5 minutes negative with the .303 Mark VII cartridge (174 grain pointed bullet, velocity over 180 feet 2380 f.s.) and about 7 minutes positive for the Mark VI cartridge (215 grain round nose bullet, velocity over 180 feet 1970 f.s.). One might figure that the high velocity bullet departed before the upward vibration occurred, and

showed only down jump at the muzzle. But practically this particular rifle, with its extremely light and thin barrel, its two piece stock, and its heavy forearm and handguard hung on the light barrel, is so extremely sensitive to jump and vibration that we would expect varying results with different cartridges. Indeed the British Text Book states with reference to this rifle; "It is essential that the rifle when in use should be periodically overhauled if its accuracy is to be maintained. The fore-end, if it warps at all, is liable to put pressure on the barrel at one or more points, and may alter or limit the vibrations, and that not consistently. The bands holding the barrel and stock together will have a similar effect if they bear tightly on the barrel. Supposing that the screw by which the barrel is held in the action be not perfectly true, it will be subjected to unsymmetrical stresses when fired. If the lugs on each side of the bolt,* or the shoulders in the body on which they bear, be not perfectly symmetrical so as to take their bearing simultaneously on firing, the small lateral movement which takes place before they can share the work equally, will be enough to give a lateral movement to the barrel and will affect the flight of the bullet in a lateral direction. The use of a bolt belonging to another rifle may thus affect the sighting." (From 1929 edition British "Text Book of Small Arms.")

Conclusions. No positive conclusions can be made from these brief and rather crude experiments. The subject of jump and vibration needs much more investigation with the modern instruments and methods which have lately come into use.

Jump in the Revolver

The barrel of the revolver is much shorter and hence stiffer than that of the rifle, and therefore there is little bend or vibration on firing and before the bullet leaves the muzzle. With the revolver the center of gravity and its point of resistance to recoil are lower in proportion to its length than with the rifle, therefore it jumps more. The velocity is low, but the barrel is short, and consequently the barrel time is short, so the bullet departs from the muzzle while the jump is approximately at its height. Therefore, if we examine a revolver closely we will see that the top of the front sight stands very appreciably higher above the axis of the bore than does the top of the notch of the rear sight. Consequently when the two sights are alined on the bullseye the axis of the bore alines at a point on the target considerably lower than the bullseye. When the revolver is fired it jumps upward and backward, and partially rotates around the grip or resistance of the hand on the grip. The bullet departs

* Unlike the Mauser type of breech mechanism, the locking lugs of the Lee Enfield action are at the rear end of the bolt.

while this jump is taking place; that is while the bore is inclined upward at an angle greater than that which it occupied at rest.

If we assume a .45 caliber revolver shooting a cartridge giving about 12,000 pounds per square inch breech pressure, then the pressure on the base of the bullet is about one ton as the base has an area of about a sixth of a square inch. As this pressure is exerted equally on all interior surfaces of the case and chamber, there is also about a ton of pressure backward, which causes the initial recoil and the upward jump. It is impossible to hold against such a recoil and jump so as to modify them to any very appreciable extent. The only reason why the revolver does not tear itself out of the hand grasp is because the recoil and jump last less than a thousandth of a second.

The weight of the revolver is much more than the weight of the bullet, hence its velocity and energy or recoil is much less than that of the bullet, in the proportion that the two weights bear to each other. In addition the weight of the hand, the arm, and the body behind the arm, and the tightness of the hand-grip must be added to the weight of the revolver. While the tightness of the grip and the rigidity of the arm do not have any very great effect on the jump, they do yet have a slight effect because we well know that holding hard for one shot and loosely for another cause the striking point on the target to vary slightly, and thus there is a loss in accuracy from variations in the hold. Also as the hold varies, so will also the trigger squeeze vary, and in the practical shooting of a handgun trigger squeeze is more important than any other factor. A very uniform hold and a perfect squeeze are essential for accurate shooting.

Apparently the amount of upward jump in a revolver, or in a single shot pistol, depends more on the weight of the bullet than on the back-thrust of the pressure, because the light bullet starts forward quicker, and leaves the muzzle sooner, and there has been less time for the gun to acquire rearward velocity and upward jump. General Hatcher has shown that with a .38 Special revolver at 20 yards, with the same sight adjustment and point of aim, a 154 grain bullet struck .22-inch high, and other bullets of 163, 177, and 210 grains weight struck progressively higher, the 210 grain bullet striking 6.28 inches high. With the 177 grain bullet a charge of 4 grains of du Pont Pistol Powder No. 5 caused an average strike of 2.26 inches high, while increasing the charge to 5 grains raised the striking point or jump only .76-inch, thus indicating that the weight of the bullet is a far greater jump factor than the velocity or pressure.

This matter of variation in jump, and consequently in location of center of impact with varying loads points to the high desirability of adjustable sights on the revolver so that it can be kept sighted to strike the point of aim with the ammunition being used at the moment.

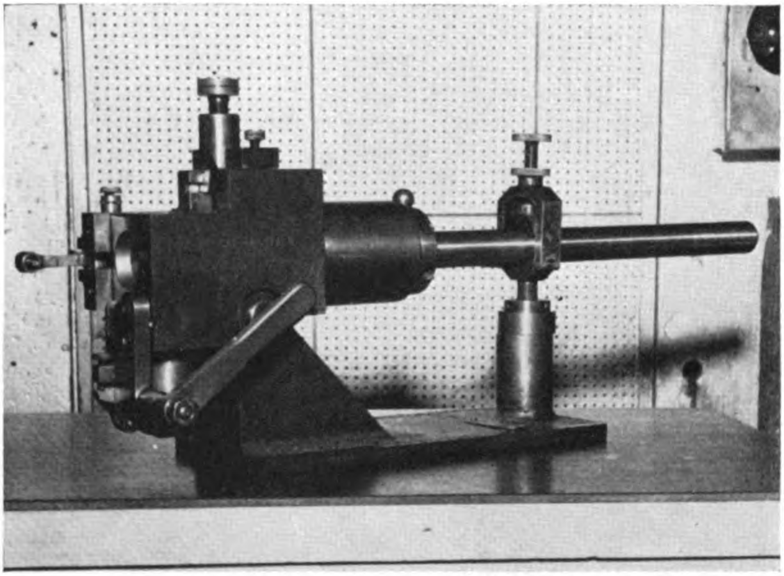


FIGURE 9A

Rifle pressure barrel and gauge mounted in Modern-Bond Universal Receiver. The arbor and thumb screw may be seen above the receiver, although the anvil and crusher cylinder are not shown. This heavy type of equipment is used for routine pressure tests of Calibers .30 and .50 cartridges where many tests have to be made each day. The ordinary pressure gauges for sporting rifle cartridges are much simpler, consisting merely of a heavy barrel screwing into a breech action, the barrel having arbor attached. Courtesy of Modern-Bond Corp.

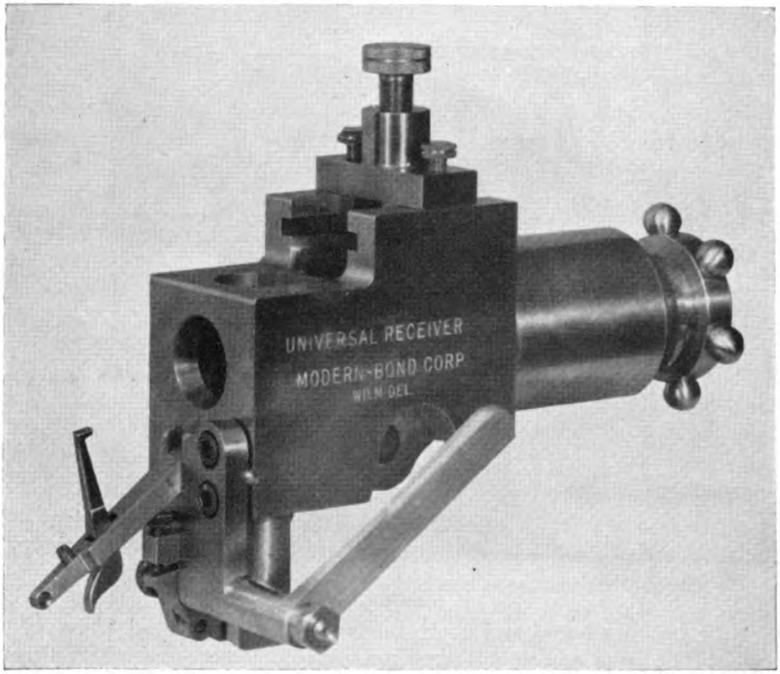


FIGURE 9B

The Modern-Bond Universal receiver for pressure guns. Showing the receiver open ready to receive the cartridge. This form of receiver, which carries the mechanism of the pressure gauge on top, is now used by all ammunition companies manufacturing small-arms ammunition for use in World War II. Any caliber of barrel, from that for the Caliber .50 machine gun down, can be screwed into it.

Jump with the Automatic Pistol

With the automatic pistol the jump is very materially less than with the revolver or single shot pistol, and the correct line of aim to strike the point of aim at short distances is much more nearly parallel to the axis of the bore. This is because, when the automatic pistol is fired, the back-thrust of the pressure is first utilized to push the slide or barrel straight back, and this movement or power is not translated to the frame and grip of the automatic pistol until the bullet has departed, or almost departed from the muzzle. Hence the muzzle does not jump up appreciably until after the bullet has left the muzzle.

Muzzle Blast

The muzzle blast, that is the compressed air that is forced out of the bore by the bullet or shot charge, and chiefly the blast of powder gas that follows the projectile, ordinarily do no useful work as they leave the muzzle. The blast directly behind the bullet does very slightly accelerate its velocity for an inch or two beyond the muzzle, but this effect is so small as to be of no consequence. In fact, this blast unused is a detriment because it results in a reaction on the part of the gun, causing the major portion of the recoil.

The powder blast at the muzzle is very powerful, depending of course on its velocity and its volume, that is on the speed with which the powder is burned and the amount burned, although some powders, such as pistol powders, burn so quickly and completely in the bore as to give only a small muzzle blast. The blast from a high power rifle fired close to a person, so that the bullet just escapes touching, but the side portion of the blast impinges, may cause a very serious wound when the person is very close to the muzzle.

This blast, while ordinarily dissipated, is yet capable of doing useful work in reducing recoil and jump. As it leaves the muzzle the major portion follows directly in the path of the bullet, but a very considerable amount flares out at the muzzle. If a baffle be secured to the muzzle of the arm, drilled in the center to allow the departure of the bullet, but so arranged that the fanning blast strikes against plates or surfaces set at right angles to the bore, then the blast will force the baffle (and the barrel to which it is secured) forward just at the instant that the blast forces the barrel and arm backward in recoil, and thus the force of recoil is reduced. This is the manner in which a muzzle brake operates.

A muzzle brake is a simple attachment secured to the muzzle of the piece. It has been applied to cannon for many years, but only recently to rifles and shotguns. It consists essentially of a steel tube screwed to the muzzle, bored through its center with a hole just

slightly larger than the bore to permit the bullet or shot charge to pass out untouched. The walls of the tube are perforated with slits or holes at right angles to the bore, or inclined backward and outward at a slight angle. The portion of the blast that fans outward strikes against the forward steel surfaces of these lateral slits or holes and drives the brake, and the barrel to which it is screwed, forward at just the instant the gun is reacting backward in recoil.

By arranging portions of these slits or holes above or on the under side of the tube a lateral force may also be imparted which can be used to reduce the jump of the piece. A good example of muzzle brake is the Cutts Compensator which has been applied to rifles, tommy guns, and shotguns, and successfully reduces the recoil. It has been very successful particularly in the case of the Thompson Sub-machine Gun (tommy gun). If that arm be fired full automatic or very rapidly, the shooter does not have time to recover from the recoil of one shot before he receives a second push or blow, and in consequence as rapid firing progresses the shooter is pushed backward, and the upward jump of the muzzle pushes the muzzle upward more and more at every shot until the barrel is almost vertical and is shooting almost straight up. Ordinarily the shooter cannot control this. But a Cutts Compensator screwed to the muzzle reduces both recoil and up-jump at the muzzle so that the shooter can hold the barrel practically alined in the direction of the target while he fires full-automatically or very rapidly.

The muzzle brake is not without some drawbacks. It turns the sound wave back more towards the shooter and thus apparently increases the intensity of the report. Some men are quite as seriously affected by loud report as they are by the energy and speed of recoil. Its weight at the muzzle affects the balance of the piece adversely unless the barrel be also shortened. And it adds to the difficulties of cleaning the bore.

CHAPTER IV

EXTERIOR BALLISTICS

EXTERIOR Ballistics is that branch of the science of Ballistics that treats with a projectile in flight; that is in its flight from the muzzle of the gun to the target, or until it strikes the ground. The flight of all projectiles through the air is quite similar. For simplicity we can liken it to a baseball or stone which we throw with the hand. If we throw a baseball or stone at an object only a few feet away it takes a straight or almost straight course from our hand to where it strikes the object. If we wish to throw the baseball or stone to an object a considerable distance away we have to throw it upward as well as forward; it starts upward at an angle, curves in its flight, reaches its greatest height at a point a little more than half way to the object, and then gradually falls until it strikes the object. Its path through the air is thus a curve or parabola. A bullet behaves in exactly the same way.

All projectiles in their travel through the air are influenced by two principal forces; the *resistance of the air,* and the *force of gravity.*

If we fire a bullet from a gun in a vacuum, and disregard the force of gravity, then it would meet no resistance from the air, and it would cover equal spaces in equal times. Referring to Figure 24, if we shot a bullet out of a gun located at M, along the line M—C, then, if it were in a vacuum (no air present), at the end of one second of flight it would reach the point A, at the end of two seconds the point B, and at the end of three seconds it would be at C; M—A, A—B, and B—C being equal.

But we know that any object travelling or flying through the air meets resistance from the air which progressively delays its forward travel. Therefore, with air present and due to this resistance the bullet fired from M would only reach a point such as A′ at the end of the first second, B′ at the end of the second second, and C′ at the end of the third second.

We also know that any object unsupported in the air at once falls to the ground from the force of gravity, and the further it falls from

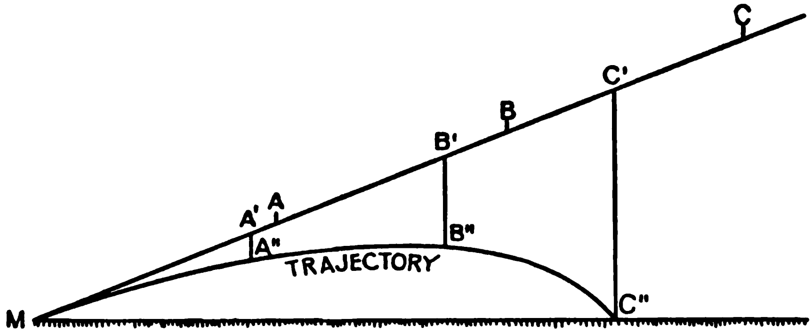


FIGURE 24

The path or trajectory of a projectile or bullet.

If a bullet were fired on a line from M to C in a vacuum, it would reach the point A in one second, the point B in two seconds, and the point C in three seconds, passing over equal spaces in equal time.

But actually it meets the resistance of the air which retards its travel so that in one second it arrives at A′, in two seconds at B′, and at three seconds at C′.

At the same time it is being acted on by the force of gravity which causes it to fall to A″ at the end of one second, to B″ at the end of two seconds, and to C″ at the end of three seconds.

The path of the bullet through the air is therefore a curve or parabola represented by M—A″—B″—C″. This curve is called the Trajectory.

This is true in principle of every projectile, whether it be a stone, a baseball, a pellet of shot, or a bullet.

this force the faster it falls. As soon as the bullet leaves the support of the gun barrel it at once begins to fall to the ground, but at the same time it is flying forward from the force of the powder. Therefore at the end of one second it will be at some such point as A″, at two seconds at B″, and at three seconds at C″. Note that in the first second it falls only a short distance from A′ to A″, but in the second second a longer distance from B′ to B″, and in the third second a still greater distance from C′ to C″, as it acquires more and more speed in its fall.

Now if we connect the points M—A″—B″—C″ with a line it forms a curve or parabola. If we examine this curve in Figure 24 we see that it is exactly the same kind of a curve that a baseball takes when we throw it to a considerable distance. This curve is called the "*Trajectory*."

The Resistance of the Air

If we walk slowly through still air we are not conscious of any air resistance. But if we run as fast as we can we at once realize that we are pushing our body against the air. Then if we walk against a very

strong wind we are still further cognizant of the air pressure or resistance. Against a wind blowing at 40 miles per hour our progress would be slowed down considerably. The writer was once in a hurricane blowing at about 120 miles per hour. He was forced to lie flat on the ground to keep from being blown away. A farmer nearby lost his corn-crib and found it a wreck on another farm two miles away. The heavy field range (cook stove) belonging to the writer's company of Infantry was blown 200 yards—all by a wind of about 120 miles per hour. At higher winds at about 150 miles per hour railroad tracks have been torn up and twisted around trees, and pieces of straw blown through tree trunks and buildings.

Well, the bullet of the little .22 Long Rifle cartridge issues from the muzzle at a velocity of 1100 feet per second, and this is also approximately the velocity of a pellet from a shotgun. At this velocity they at once encounter an air resistance comparable to a wind of 752 miles per hour! The .30-06 bullet starts off at 2700 f.s. and encounters a gentle breeze of 1,841 miles per hour which reduces its velocity to 2460 f.s. by the time it has reached 100 yards, 2,240 f.s. at 200 yards, and 1068 f.s. remaining velocity by the time it has reached 1,000 yards. Similarly the .220 Swift bullet, starting at 4140 f.s. meets a wind of 2,823 miles per hour, which brings its velocity down to 3490 f.s. in the first one-hundred yards. So it will be appreciated that air resistance really amounts to something.

Projectiles and bullets vary in their ability to maintain proportions of their initial velocity against air resistance according to their sectional density and shape. A light ball of cotton cannot be thrown far even into still air, and against a stiff breeze it will travel only a few feet before it is blown back towards the thrower. On the other hand an arrow can be shot successfully into a gale.

Bullets, in their ability to maintain their velocity in air, may be likened to boats in water. One cannot get up much speed in a flat pointed scow, and the minute he ceases to row the scow very soon loses headway. But the racing yacht, sharp pointed at both ends, and narrow in proportion to its length, continues to glide a long way when the power is shut off. With a bullet the propelling force is of course shut off as soon as the bullet leaves the muzzle. It has then only its momentum and remaining energy and velocity to carry it along, and these are continually being hammered down by air resistance.

Let us look at certain forms of bullets and see how well they will maintain their velocity against air resistance. See Figure 25. The round ball is the poorest form in this respect, losing its velocity very rapidly. Round lead bullets fired from old muzzle loading rifles were useless beyond 400 yards, and small shot fired from a shotgun will not fly beyond 300 yards.

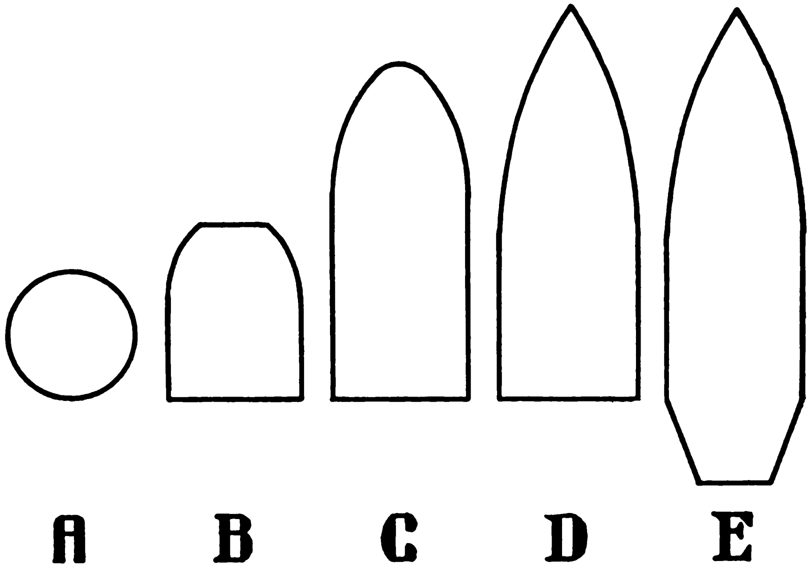


FIGURE 25
Bullet forms, from left to right, in the order of their ability to maintain velocity against air resistance.

The short, blunt nose cylindrical bullet B was better in this respect because it had greater sectional density—that is weight in proportion to its diameter. The old .32-20 cartridge shot a 100 grain bullet of this type at a muzzle velocity of 1280 f.s. Due to air resistance its velocity fell off to 1060 f.s. at 100 yards, and when the rifle was sighted for 100 yards the bullet dropped 24½ inches at 200 yards.

Longer round nose bullets such as C, representing a .30-30 bullet of 170 grains, had greater sectional density and maintained their velocity better. Starting at 2200 f.s., the velocity at 100 yards is 1930 f.s.

A long, sharp pointed bullet like the .30-06 service bullet shown at D is still better, its remaining velocities being given above. The stream lined or boat-tailed bullet shown at E is the best form of all for maintaining a good percentage of its velocity against air resistance. With bullets of equal sectional density a sharp point is best for maintaining velocity while the bullet is still flying at a high speed, but as the velocity is reduced to about the velocity of sound (1100 f.s.) a taper to the rear becomes of importance, and the shape of the point is not so essential. Long range bullets, artillery projectiles, and buzz-bombs which start off at high velocity, but have to

maintain their flight for long distances where their velocity has been reduced below the velocity of sound, are both sharp pointed and boat-tailed. But airplanes and racing cars, which do not exceed the velocity of sound, are tapered at the rear only, a blunt or tear-drop shape having been found better for the front or leading edge.

Bullets, or at least their cores, are made of lead which is the heaviest cheap metal that will give them the very desirable high sectional density. It will readily be seen that a lead bullet will maintain its velocity and flight better than one of a lighter metal such as aluminum.

There is nothing at all complicated about this matter of the ability of a bullet to maintain its velocity against air resistance. It is a simple matter to look at any two bullets differing in form and length, and tell at a glance which will maintain its velocity best. As we will see later in Chapter VI, the sectional density of the bullet and its form of point and base are used to establish a **Ballistic Coefficient C** which is an index of the ability of the bullet to overcome air resistance, maintain a good proportion of its velocity, and fly with a flat trajectory. The larger the Coefficient C the more efficient the bullet is. Maintenance of velocity is of course of the utmost importance because it means greater velocity at long ranges, flatter trajectory, and greater sustained killing power.

The Force of Gravity

If we take a bullet and place it in the muzzle of a gun barrel it will remain there, held by the barrel. If we now insert a cleaning rod from the breech and very gently push the bullet out of the muzzle it will fall to the ground, and will strike the ground just below the muzzle. All bodies, as soon as they are turned loose from support and become free in the air act in the same way. The earth attracts them, and this is called the force of gravity.

When a body or a bullet falls from gravity its velocity of fall will not be constant throughout the entire fall, but will increase at a uniform rate, which is called the *acceleration of gravity,* and is expressed in feet per second.

When a body falls freely in this manner it will have attained at the end of one second a velocity of approximately 32.2 feet per second. Thus the average velocity during the first second will be 16.1 f.s. Since the velocity increases at a uniform rate it will be 64.4 f.s. at the end of two seconds, and the space fallen through during this second will be 48.3 feet.

The average velocity of the object for any second is the average of the velocity at the beginning and the velocity at the end of that second.

Thus:

Velocity at beginning of 1st sec.	00.0 f.s.
Velocity at end of 1st sec.	32.2 "
	2)32.2 "
Average velocity for 1st sec.	16.1 "
Velocity at beginning of 2nd sec.	32.2 "
Velocity at end of 2nd sec.	64.4 "
	2)96.6 "
Average velocity for 2nd sec.	48.3 "
Velocity at beginning of 3rd sec.	64.4 "
Velocity at end of 3rd sec.	96.6 "
	2)161.0
Average velocity for 3rd sec.	80.5 "

As the space fallen through in any given second is equal to the average velocity for that second, it follows that the total distance fallen through at the end of any given second is equal to the average velocity up to the given point multiplied by the number of seconds during which the object has fallen. For example:

Initial velocity	00.0 f.s.
Velocity at end of 3rd sec.	96.6 "
	2)96.6 "
Average velocity for first 3 sec.	48.3

$3 \times 48.3 = 144.9$ feet, space fallen through in the first three seconds.

The above theory supposes a body to be falling freely in a vacuum, but while the air will offer a resistance and somewhat reduce the actual motion, the resistance is extremely small for the first three seconds of fall at these low velocities. Acceleration due to gravity decreases at high altitudes, and increases as ~~we go be~~low the surface of the earth. All these variations on the earth's surface are so small that they hardly need to be considered in practical problems in small arms ballistics. Thus the acceleration due to gravity may be considered as 32.2 f.s. each second.

This is true of all bodies of fair weight and sectional density, such as stones, baseballs, and bullets. The only exceptions are objects which are extremely light for their size and bulk. A leaf or a tuft of cotton would fall comparatively slowly because of its poor weight and shape to overcome any air resistance.

Because there is often argument about this simple fact, it must be emphasized here that the bullet *always* starts to drop, and drops at this rate and acceleration, just as soon as it has left the muzzle of the gun. That is it always drops from the line of prolongation of the axis of the bore as that line exists at the instant of discharge. This

is known as the **line of departure.** Because of the jump, as explained in the last chapter, we will be more correct if we say that the bullet drops from the line of prolongation of the last few inches of axis of bore at discharge. But it is also correct to say that the bullet starts to drop at the instant it leaves the muzzle, which is the same thing, and that in the first second of its flight through the air it will drop 16.1 feet from the muzzle.

Of course while the bullet is dropping from the force of gravity it is also moving forward much more rapidly from the force of the expansion of the powder gases, and the bullet will not drop to the ground at a point directly under the muzzle, but at a point very far distant in front of the gun. Take, for example, the 150 grain bullet fired from our .30-06 service rifle at a muzzle velocity of 2700 f.s. It leaves the muzzle at 2700 f.s. and it falls 16.1 feet in the first second, but during that second it has likewise flown forward approximately 650 yards; not 2700 feet or 900 yards, because its velocity is constantly being diminished by air resistance. Thus if the rifle barrel were suspended horizontally 16.1 feet above a level plane of ground, the bullet, dropping from gravity would strike the ground 650 yards in front of the muzzle.

The time of flight of this bullet for the first 100 yards is only .116 second. In that short time, the bullet starting to drop at zero from the muzzle, would drop a very small amount indeed. In fact, in the first .116 second it drops only about 2.4 inches. Therefore if we were to point the rifle barrel at a target one hundred yards away, so that the line through the axis of bore was projected to the center of the bullseye, the bullet would strike 2.4 inches below this center, that being the drop from gravity over 100 yards.

Wind Deflection

In addition to air resistance and gravity, there are other forces that influence the flight of the bullet through the air. Wind, if it be present, will cause the bullet to drift with it, in proportion to the velocity and direction of the wind. Thus a wind blowing from the shooter's right will cause the bullet to deviate to the left of the plane of fire. Rear winds accelerate the flight of the bullet slightly, and head winds retard it, causing the bullet to fly with either a slightly flatter or a more curved trajectory, and to strike slightly higher or lower on the target, than it would if no wind were blowing. Wind deflection will be made the subject of a separate chapter further along in this book.

Drift

In rifles there is a tendency for the bullet to drift slightly to the right of the plane of fire if the bore is rifled with a right hand twist,

and to the left from a left hand twist. For many years ballisticians have been endeavoring to explain the cause of this drift without conspicuous success. Very recently one scientist endeavored to explain the cause of drift briefly, to the extent of about sixty pages, and wound up by referring the reader to a number of learned treatises on physics should he desire to pursue the subject further.

As explained in Volume I, a cylindrical bullet fired from a rifle is to be regarded as a gyrostat which tends to keep its point to the front and its axis in the same plane, and it resists strongly any force which attempts to drive it from this plane. This is why a rifle bullet flies with good accuracy. The principles which govern the motion and energy of a gyrostat are the same as those which govern the movements of the earth, and are thus a subject under celestial mechanics. This is why a scientific explanation of drift is so difficult. The present writer trusts that he can be a little more successful than the author of the sixty pages.

The bullet, a gyrostat, endeavors with all its might to maintain the direction of its longer axis parallel to the line that axis had in the bore of the rifle, where it was made into a gyrostat by the spin of the rifling. Thus the bullet endeavors to fly with its axis parallel to its line of departure, or to the prolongation of the axis of the bore, rather than to follow the curve of the trajectory with its axis, as shown in Figure 26. That is, the bullet tends to keep its spinning axis pointed at the same star.

While the bullet is flying forward it is also dropping from the force of gravity, and hence the direction of air resistance is not head on to the bullet, but is at an upward angle approximately on the line A—B. Thus as the air resistance is below the bullet it acts to raise the nose of the bullet slightly, or to try to do so against the gyrostatic force, as the major portion of the air resistance falls on the nose portion.

From studies of gyrostats we know that any force endeavoring to drive it out of line actually sends it out at right angles. Thus if the gyrostat or bullet is rotating to the right any force such as the resistance of the air on the line A—B tending to force the nose of the bullet up, instead of doing that, forces it out to the right. Thus if the twist of the bullet (rifling) be to the right, the air resistance tends to turn the point of the bullet very slightly to the right of the plane of fire, causing the bullet to drift to the right. The opposite is true of a left hand twist.

However, his discussion is purely academic because the drift with rifles, and at rifle ranges is so slight that it is not apparent, for it is less than other inaccuracies which are always present.

With our old .45-70 Springfield Model 1873 rifle firing a 500 grain bullet at M.V. 1315 f.s., from a right hand twist of one turn in 22

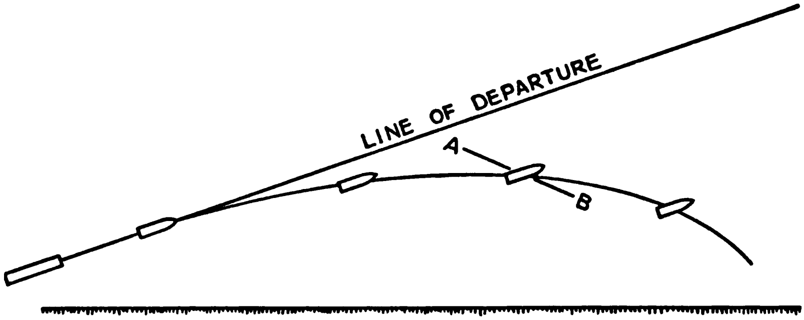


FIGURE 26

Due to its gyrostatic stability a cylindrical bullet tends to maintain its longer axis parallel to the line of departure from the muzzle, instead of this axis following the path of bullet or trajectory curve.

The direction of air resistance is therefore approximately on the line A—B because the bullet is falling from gravity as well as travelling forward.

inches, the drift is to the right and amounts to 1.29 inches at 100 yards, 3 inches at 200 yards, 11.5 inches at 500 yards, and 43.2 inches at 1,000 yards.

With the U.S. Magazine Rifle, Caliber .30, Model 1898 (.30-40 Krag) firing a 220 grain bullet at M.V. 2000 f.s. from a barrel 30 inches long with a ten inch right hand twist, there is a jump to the left from the plane of fire, probably due to the bolt of this rifle having only one locking lug. This jump causes the bullet to pass 2.5 inches to the left of the plane of fire at 100 yards, and 4.3 inches left at 200 yards, reaching its maximum left deviation at 600 yards where it is 8.5 inches. This left jump is being constantly diminished by the right drift, which has neutralized it at 1,100 yards. At 2,000 yards the drift is 52 inches right. With the carbine, which has a 22 inch barrel the drift is always right.

With the U.S. Rifle, Caliber .30, Model 1903 (Springfield) firing a 150 grain pointed bullet at M.V. 2700 f.s. from a barrel 24 inches long, with a 10 inch right hand twist, there is also a jump to the left amounting to .26 inch at 100 yards and .45-inch at 300 yards, but this jump is entirely negatived by the right hand drift by the time the bullet has reached 500 yards, where jump and drift are no longer in evidence. The right hand drift from then on amounts to 13 inches at 1,000 yards.

The drift with the above three U.S. Government rifles was obtained by experimental firing with two rifles, one having a right handed, and the other a left hand twist, the two rifles being fired simultaneously.

Yaw

Given a good rifle and ammunition, then the extreme spread of a series of shots at different ranges will be approximately in proportion to the range, and in screen firing the pattern of the group at long range will bear a close resemblance to that at short range. Thus, in still air, if we shoot through a thin paper screen placed at 100 yards on to a target at 500 yards, and the extreme spread of the group on the 100 yard screen is 2 inches, that on the 500 yard target will be approximately 10 inches. Also the highest, lowest, right, and left shots on the 100 yard screen will likewise strike in the same relative position on the 500 yard target, or course assuming an accurate rifle and ammunition. But naturally when shooting in a wind there will be more displacement at the long range.

This is true in mechanical shooting from a reliable machine rest, but it is not true to quite such an extent when the rifle is aimed by eye for each shot. Then the deviation at longer ranges is a little greater than in proportion to the distance, as the atmosphere is never perfectly clear, and aim will be more difficult and will contain more errors at the longer distances. Thus with a spread of 2 inches at 100 yards, on a clear day and with a telescope sight we might expect a spread of about 12 inches at 500 yards instead of 10 inches.

Occasionally, however, we find a rifle and ammunition where the above does not hold true at all. That is, the 500 yard target group bears no relation to the 100 yard screen group, although if a screen were also placed at 200 yards, the 200 and 500 yard groups might be closely related. A number of reliable tests have been made in screen shooting through a screen at 100 yards on to a target at 200 yards, where the two groups have no similarity to each other, and where the 200 yard group has a smaller extreme spread with respect to the distance, than the 100 yard screen group. Thus the 100 yard group might show an extreme spread of 1.7 inches, and the 200 yard group only 2.4 inches

This is due to what ballisticians term *"Yaw."* The bullet was slightly unbalanced when it left the muzzle, it was not flying strictly with its point to the front, but instead had an air spiral, and it did not steady down in its flight until it had passed 100 yards. The action is probably similar to that of a top which wabbles slightly when it starts to spin, and does not steady down and "go to sleep" until it has spun for several seconds. Yaw, when present, is usually seen at targets at 50 and 100 yards, but usually disappears by the time the bullet has travelled 200 yards, and beyond that distance the bullet may fly with excellent accuracy.

While some yaw is probably always present at short ranges, it is usually so small that it is not appreciable, and will not be clearly in

evidence on the targets. Yaw in clear evidence is quite rare and can only be proved by screen shooting. Of course a bullet may wabble, tip, have an air spiral, be inaccurate at short ranges, and continue to do this at long ranges, but we do not usually refer to this as yaw, but rather as inaccuracy due to lack of gyrostatic stability from any one of a number of causes.

Wabble, tip, and **air spiral** are terms used to describe the flight of an imperfect bullet through free air. These terms are used rather loosely. No bullet is perfect; all are more or less deformed or unbalanced as manufactured, and are still more unbalanced by being forced through the rifled bore. They all wabble, tip, and have more or less of an air spiral. Could we make a perfect bullet and drive it through the bore without deforming it, and deliver it perfect from the muzzle, it would then fly in a straight line to the target (disregarding the fall from gravity) and all such bullets would strike in the same hole in the target—we would thus have perfect accuracy. We can do nothing *perfectly,* but we can sometimes do some things mighty well. Yesterday the writer received three targets, five shot groups, shot at 200 yards. All of them were less than one and one-half inches extreme spread.

It is difficult to differentiate between wabble, tip, and air spiral, for if a bullet wabbles it will tip, and if it tips it will have an air spiral. But very roughly we may say that when a bullet wabbles it is not flying strictly point to the front all the time. If fired through a series of paper screens placed at various distances it may make a slightly oblong hole through the first screen, a perfectly round hole through the second, and a more oblong or key-hole through the third. A series of such bullets when fired at a target may tip or wabble differently, and will make a rather large group—poor accuracy. Such bullets have been rather poorly made, or they have been deformed in the bore, or the twist of rifling is not sufficient or too great to give them perfect gyrostatic stability.

A tipping bullet, as differentiated from the above, is one, the point of which tips slightly to one side as it leaves the muzzle so that it starts off at a tangent to the regular line of flight. It will then strike to the right (or any other direction) from the center of the normal group at, say, 100 yards, and about double that distance away in the same direction at 200 yards. A tipping bullet is one that has an imperfect base so that just as it leaves the muzzle the gas rushes out at one side, instead of rushing out evenly all around the base, and this gas tips the point of the bullet to the opposite side. If we beveled the muzzle of the rifle we could thus make every bullet tip, but to the same side. We would thus alter the line of flight, but that altered line would still be fairly accurate because each bullet would tip equally.

An air spiral is caused by a bullet that is unbalanced so that its center of form does not correspond with its center of gravity. When it leaves the muzzle and passes into free air it starts to revolve or rotate around its center of gravity instead of its center of form, and the air resistance causes it to fly in a spiral path like a cork-screw greatly elongated. At 100 yards (say) it may strike to the left of the center of the normal group, at 200 yards above the normal group, at 300 yards to the right, and at 400 yards below it, at a constantly increasing distance from the normal group. We can intentionally cause an air spiral and see it clearly by firing through screens, by drilling a small hole in one side of a bullet, thus removing some metal and unbalancing it. A lead bullet or a lead core may have a blowhole somewhere within the lead thus unbalancing the bullet, or a jacketed bullet with the wall of the jacket (lighter metal) thicker on one side than the other will also be unbalanced and will shoot with more or less of an air spiral.

Dr. F. W. Mann's work, "The Bullet's Flight," contains a very exhaustive treatise of the flight of unbalanced bullets, and the cause thereof.

When we succeed in obtaining well made bullets, and we fire them at a uniform velocity through a bore having the proper twist of rifling, and the bullets are not unduly deformed at the muzzle, then they will make round holes in the targets, showing that they are flying fairly point to the front. If they make a small group it indicates that none are tipping seriously. If there is no wind to deflect them and we fire them through a screen at 100 (or 300) yards onto a target at 200 (or 600) yards, then the bullet which strikes at the top of the group, (or its right or left or bottom) on the screen will also strike at the top (or right, left, or bottom) on the target, so that the dispersion of the individual bullets will be much the same, and the two groups will have very much the same appearance, also the group at the target will be only very slightly more than twice as large as the group on the mid-distance screen, showing that there was practically no air-spiral flight.

Accuracy

As accuracy of flight depends primarily on the proper delivery of a perfect bullet-gyrostat from the muzzle, its discussion really falls under Design and Interior Ballistics. The factors which make for accuracy were thus very fully discussed in Volume I. But the whole science of ballistics is directed to that knowledge of the subject, and to that perfection of materiel which will enable us to hit an object, however small, at a distance, and it would therefore seem to fall under the heading of ballistics quite as much as under design. It will therefore be considered hereafter in a separate chapter.

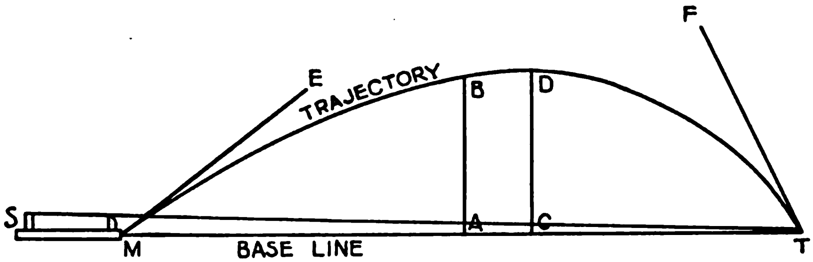


FIGURE 27

Trajectory Nomenclature and Definitions

M—Muzzle of Gun. **T**—Target.

Range—A distance measured along the line of aim.

Base Line—The straight line connecting the center of the bore at the muzzle with the bullet hole in the target. M—T

Trajectory—The curved path of the projectile from center of bore at muzzle to center of bullet hole in target.

Mid Range Trajectory Height—The vertical distance from base line to trajectory curve at mid range. A—B

Summit of Trajectory—The vertical distance from base line to highest point in trajectory curve. C—D.

Line of Aim—The straight line connecting the rear sight, front sight, and point of aim on target. S—T

Line of Departure—A line tangent to the trajectory at the muzzle. It coincides with the axis of the bore when there is no jump. M—E

Angle of Departure—The angle formed by the line of departure and the base line. E—M—T

Angle of Elevation—The angle of departure plus or minus the jump.

Range is stated in yards.

Trajectory Heights are usually stated in inches, except that in ballistic computations they must be stated in feet.

Angles are stated in degrees, minutes, and seconds.

One Minute of Angle subtends 1.047 inches at 100 yards.

Velocity and Time of Flight are stated in feet per second (f.s.)

Energy is stated in foot-pounds.

CHAPTER V

Trajectory—A Study

WE HAVE seen in the previous chapter that the path of the bullet, or trajectory through the air from muzzle to target, is a curve or parabola. Also that the further the target is from the muzzle the more curved the trajectory will be in order that the bullet will reach the target. In addition, the faster the bullet travels the flatter or less curved the trajectory will be over a given distance because the bullet covers the distance in less time and is not acted on for so long by the force of gravity. But the trajectory is always a curve, and thus we must point the barrel up at least a slight angle for a short distance, and a greater angle for a longer distance to cause the bullet to ascend enough to overcome the force of gravity that acts during the time it takes the bullet to reach the target. The barrel and bore are therefore never pointed or aimed directly at the bullseye, but rather at a point more or less above it, and the greater the distance the greater must be this *angle of elevation*. Also the higher the velocity of the bullet the less will be this angle of elevation for any range.

The Sights

We would never accomplish any good shooting by merely guessing how much to elevate the barrel in order to strike the bullseye at any given distance. If we knew the angle of elevation for each distance we could elevate the barrel by means of a clinometer, which measures the angle between the straight line joining the muzzle with the target and the upward angle of the barrel, and this in effect is what we do. The front sight near the muzzle, and the rear sight near the breech form together what is really a clinometer. The rear sight is adjusted to stand a little higher above the axis of the bore than the front sight, so when we bring the two sights and the bullseye into alinement the barrel and bore are actually pointed slightly upward at the angle of elevation sufficient to cause the bullet to rise and fall so as to strike the bullseye. By making the rear sight adjustable to various angles we can adjust it for any desired range, higher for a long range than for a short range. See Figure 28.

With small, inexpensive .22 caliber rim fire rifles the rear sight is made of a standard height which will give the barrel sufficient eleva-

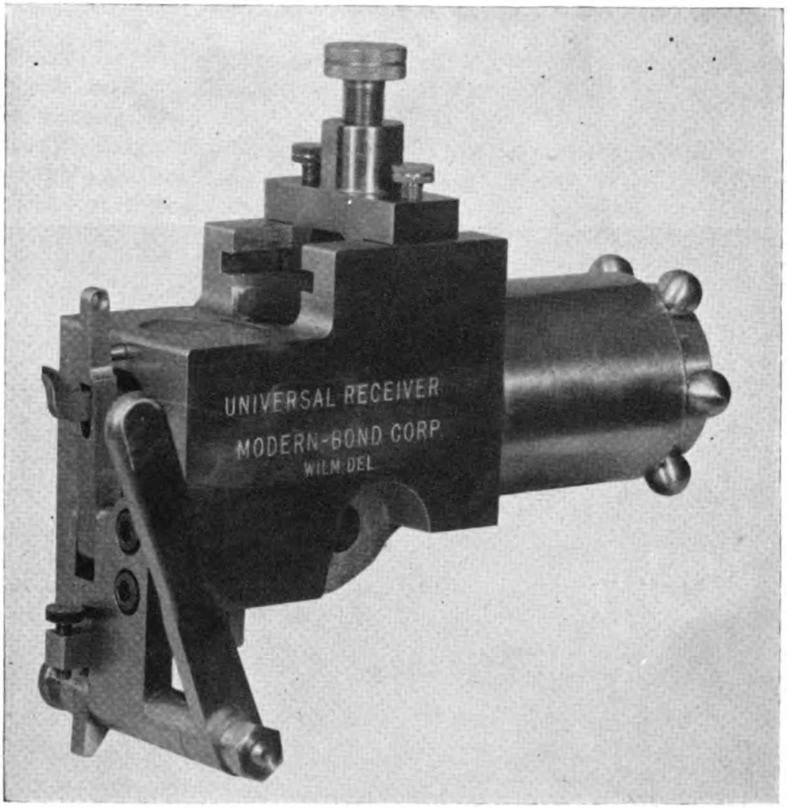


FIGURE 9C

Showing the Universal pressure gun receiver loaded, closed, and locked. The thumb screw which tightens the anvil and crusher cylinder down tight against the piston can be seen on top of the receiver.

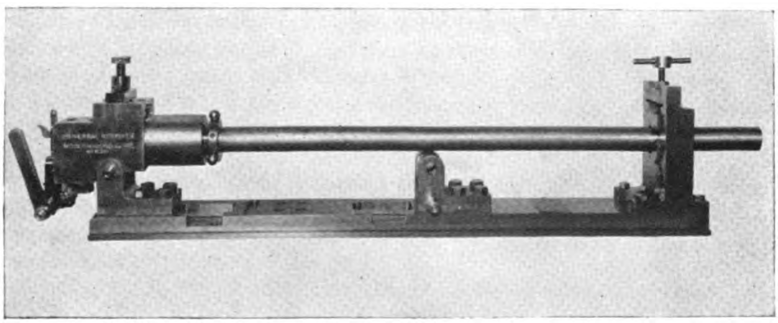


FIGURE 9D

The pressure barrel is here seen screwed and clamped into the Modern-Bond Universal Receiver, the assembly being held in the slide, which in turn is mounted in the movable base of the Frankford Arsenal Machine Rest, as shown in Figure 43. When the gun is fired the entire assembly as shown above slides to the rear in recoil through the track of the movable base shown in Figure 43.

FIGURE 12

A home made chronograph, showing cardboard discs on either end of the long shaft of a constant speed electric motor. This is believed to be the first chronograph constructed on this principle, and is shown on the first experimental range of Dr. Franklin W. Mann.

tion to cause the bullet to strike the bullseye at a distance of about 25 yards, no further refinement being demanded in these cheap and short range rifles.

But with all larger rifles of greater ranging ability the rear sight is adjustable so that it can be lowered to the bottom of its slide for shooting at the shortest distance, or elevated more and more as shooting is conducted at more distant targets. Figure 28 also shows a simple military rear sight, with the slide graduated in hundreds of yards of range, and set at 100 yards. When set at 100 yards, and the correct aim taken, the barrel is elevated to the angle of elevation necessary to strike the target at 100 yards.

Certain of the cheaper adjustable rear sights merely have a scale on the slide, or on what corresponds to the slide, with graduations about $\frac{1}{20}$th inch apart. The shooter is supposed to sight in his rifle at various distances and find out by trial and error how far up on

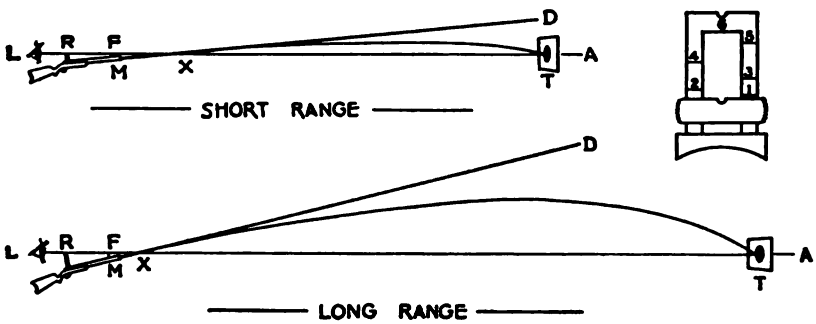


FIGURE 28

To aim a small arm with precision it is fitted with two sights, the front sight F, and the rear sight R. These two sights are alined with the bullseye T, and that line L—A is termed the "Line of Aim."

At a short range the rear sight is adjusted with a low elevation, and when aim is taken it results in the barrel being inclined upward at a slight angle, and the flat trajectory meets the bullseye. The bullet, starting from the muzzle M below the line of aim, cuts that line at X, and then rises and remains above the line of aim until gradually curving and falling, it strikes the bullseye at T.

For a long range the shooter elevates the rear sight more, and when he aims the barrel is inclined upward at a greater angle, resulting in the more curved trajectory necessary to reach the more distant target.

The line M—D is the line of departure of the bullet from the muzzle. Note that the trajectory or path of the bullet is always below this line, never above it, because the bullet starts to drop from this line, due to the force of gravity, as soon as it leaves the support of the barrel.

All worthy rear sights are adjustable so they can be set at a low elevation for short ranges, or higher for long ranges. The sketch shows a military rear sight, graduated for hundreds of yards, with the slide set at the 100 yard setting on the leaf.

this scale he has to adjust the bar containing the notch or peep hole for each distance. This is not a very convenient arrangement.

Minutes of Angle

We now come to the still greater refinement of adjustment required for accurate and skilled rifle shooting, and for serious study and experiment in exterior ballistics. Ballisticians and trained riflemen state the angles to which the rifle barrel and the axis of its bore must be elevated to strike the bullseye at various distances in terms of minutes of angle. In the appendix will be found a table of angles of elevation for all common cartridges showing the angle to which the barrel and sights must be elevated to strike the bullseye.

These elevations are all stated in terms of minutes of angle. A minute, that is $1/60$th of a degree, subtends 1.047 inch at 100 yards. That is from a point, if we draw two lines departing at an angle of one minute, and extend these lines to 100 yards, at that distance they will be 1.047-inch apart. In practice riflemen call this one inch. Thus the rifleman, to make it simple, memorizes the sentence *"One minute equals one inch per hundred yards."* A minute also equals 2 inches at 200 yards, 5 inches at 500 yards, 10 inches at 1,000 yards, etc. This is very simple, and the student is asked to fix it firmly in his memory from now on.

Suppose we are on the rifle range and are sighting and zeroing a rifle and cartridge at 100 yards, and by trial and error shooting, and moving the rear sight, we arrive at the correct adjustment for 100 yards. We will call this adjustment "zero." Suppose further that our cartridge is of such velocity and trajectory that the bullet in flying from 100 to 200 yards drops six inches. Then to strike the bullseye at 200 yards we would have to give the rear sight an additional angle of elevation above zero to overcome this drop of 6 inches. Thus we would elevate our rear sight three minutes because at 200 yards three minutes equals six inches. See the preceding paragraph. This would be equivalent to aiming the barrel six inches higher on the 200 yard target. As an example of the tables of angles of elevation we give here one for a .30 caliber 150 grain sharp pointed bullet at a muzzle velocity of 2700 f.s.; the old .30-06 service cartridge: *

100 yards	0.0 minutes	600 yards	18.3 minutes
200 "	2.8 "	700 "	23.7 "
300 "	5.8 "	800 "	30.1 "
400 "	9.4 "	900 "	37.5 "
500 "	13.5 "	1000 "	45.9 "

* Most tables of elevation start with the muzzle as zero, and give a 100 yard angle which also contains the jump, must therefore vary with every rifle, and needlessly complicates matters. The writer, in this work, prefers to start zero at 100 yards where most rifle shooters sight their rifles in basically.

With such a table, and with a rifle having a rear sight adjustable in minutes, if the shooter has found his correct adjustment for one range he at once knows it for all other distances. Much other useful and important data can be obtained from such a table as will be seen in the next chapter.

Let us now examine the scale or graduations of minutes on a modern rear rifle sight. Suppose that on our rifle the front and rear sights are 36 inches apart. In 100 yards there are 3,600 inches. 3,600 divided by 36 gives us 100. Therefore any movement of the rear sight will result in a movement one hundred times as large on the target at 100 yards. A movement of $\frac{1}{100}$ inch on the rear sight would move the striking point 1 inch at 100 yards, or 1 minute, as a minute equals one inch per hundred yards. Similarly, if the front and rear sights were only 24 inches apart one minute would be $\frac{1}{150}$th inch on the rear sight. Or with a telescope sight, if the front and rear mountings are 7.2 inches apart a one minute graduation would be $\frac{1}{500}$ inch.

Of course it is impossible to see any such small graduations on a simple scale. The smallest graduation that the naked eye can well see is $\frac{1}{50}$th inch. Therefore in order that we can see, move accurately from one to another, and make a record of these minute adjustments, the scales on modern rear sights are constructed on the principle of the micrometer or vernier. The micrometer system is used almost exclusively in the United States, while in England the vernier is often employed.

The micrometer, as applied to our sights, is exactly the same in principle as the machinist's micrometer for measuring thousandths of an inch. The simplest micrometer is that seen on the Lyman No. 48 rear sight, A in Figure 29. The graduations on the slide are in multiples of five minutes each, while the screw head at the top has five numbered minute graduations around its circumference, and for refinement each of these graduations or minutes is sub-divided into quarters. If we turn the screw head one numbered graduation we move the sight adjustment one minute. If we revolve it a full turn we change it five minutes and in doing so the pointer on the lower scale will show a change of one graduation or five minutes. Figure 29 A shows the Lyman 48 rear sight set at 6 minutes, that is five minutes on the slide at the bottom plus 1 minute on the screw head. To read a micrometer, read the slide or straight scale first, and add to it the reading on the head of the screw.

The Redfield micrometer rear sight operates on the same principle as the Lyman No. 48 sight, the only material difference being that the graduations on the slide are in multiples of three minutes instead of five, each fifth graduation being longer than the others, and numbered 15-30-45-60.

With the usual target telescope sight the blocks on the barrel, and hence the front and rear mounts, should be located 7.2 inches apart. With such a short radius a minute adjustment will require the very small movement of $\frac{1}{500}$-inch, and even that movement is not quite small enough for the fine shooting we usually wish to do when we place such a telescope on a rifle. Therefore the micrometer must be a little more refined than in the case of iron sights, but the principle

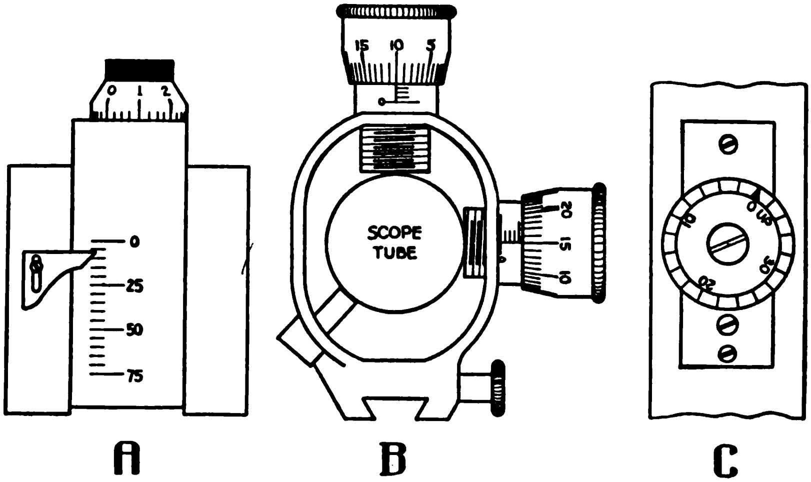


FIGURE 29. MICROMETER SIGHT ADJUSTMENT

A. Lyman 48 sight. Scale on slide reads in divisions of 5 minutes. Around the screw head there are five 1-minute divisions, each divided into quarters. Sketch shows sight reading 6 minutes—5 on slide, plus one on head.

B. Micrometer rear mount of target scope. Elevation on top reads 3 graduations on slide, each being 25 half-minutes, plus 10½ half-minutes on barrel—85.5 half minutes elevation. Windage on the right similarly reads 100 on slide plus 15 on barrel—115 half minutes windage.

C. Reticule dial on Lyman Alaskan scope. Each graduation is two minutes. Reading is 3 minutes elevation.

is exactly the same. The graduations on these telescope mounts are in *half minutes* instead of minutes. A half minute, of course, equals ½-inch at 100 yards, or 1 inch at 200 yards.

Figure 29 B shows this rear mount. The slide is graduated with lines which are 25 half minutes apart, and each fourth graduation is longer than the others indicating 100 half minutes. The barrel of the screw has 25 half minute graduations around its circumference, each fifth graduation being numbered 5-10-15-20. Unscrewing the barrel of the screw one graduation raises the elevation a half minute. A full rotation of the barrel and screw moves it 25 half minutes across one graduation on the slide. The figure shows the elevation

micrometer at the top set at 85½ half minutes. The windage micrometer at the side operates exactly the same way, and the sketch shows it set at 115 half minutes. Unscrewing the top (elevation) micrometer acts to raise the elevation to a greater range, or to raise the center of impact on the target. Unscrewing on the right (windage) micrometer acts to take windage to the right, or to move the center of impact to the right on the target. Furthermore, as a necessary added feature for refined and accurate shooting, the barrel heads on this mount are arranged to "click" for each *quarter minute*, and this click can be felt with the fingers as the screw is rotated. A quarter minute can also be seen by the index line being half way between two graduations on the barrel. It is thus possible to click the sight by feel without having to get out of firing position to get the eye close enough to the scales to see them. Of course it has to be clicked twice for a half minute change, or four times for a full minute. A click or quarter minute, of course, has an adjusting value of ¼-inch per hundred yards.

In this connection it is interesting to note the convenience of the official National Rifle Association targets. The 10-ring in the center of the black bullseye is 2 minutes in diameter at all distances, and the other scoring rings are one minute apart. Therefore with a hit anywhere on the target, it is easy to adjust the micrometer sight just the right amount to move the center of impact into the center of the 10-ring.

The tube of the Lyman Alaskan scope, and of many other big game hunting scopes, is solidly set on the rifle and does not move. Instead the reticule is adjustable by means of elevation (on top) and windage (on side) dials which are secured to the outside of the tube. Figure 29 C shows the elevation reticule dial on the Alaskan scope. It is graduated with lines two minutes apart, and is arranged to click for each half graduation or minute. An arrow shows which way to turn the dial to move the elevation up or down. The sketch shows the dial set at three minutes elevation.

The rear sight on the Garand semi-automatic rifle is graduated in hundreds of yards of range as is common on military rifles, but the adjusting screw is also arranged to click for each minute of adjustment, so that it is possible to make changes of minutes or inches on the target.

The windage micrometers on all of our iron sights are arranged on the same principle, but with slightly different reading. The original rear sight on the .30 caliber Springfield Model 1903 rifle was arranged with the windage scale having lines that were four minutes apart, and these lines were called "points." Riflemen thus came to speak about their windage adjustments in "points, or quarter points of windage." A point is thus 4 minutes, or four inches per

hundred yards. Since then all windage slide scales have likewise been graduated in lines or points of four minutes. The slide graduation therefore is in increments of 4 minutes, and the screw head has four major graduations on it, each being a minute. These major graduations are usually further divided into quarters, each being a quarter minute.

In addition to allowing precise adjustment for range, and horizontally for windage, all these micrometer sights permit perfect control of the location of the center of impact on the target. Suppose that the shooter has set his sight for 200 yards, but after repeated shooting at that distance he finds that his bullets average striking the target four inches below the center of the bullseye. If he will then raise his elevation two minutes and aim exactly as before, his bullets will average striking exactly in the center of the bullseye—because two minutes equals four inches at 200 yards.

The student must get firmly fixed in his mind the fact that this matter of sight adjustment is merely a matter of angle. The curve of the trajectory has nothing to do with it, once the elevation for a given distance has been found. One minute equals one inch of adjustment per hundred yards always. Of course if we are using a cartridge of low velocity and curved trajectory, the bullet will drop more when flying from one range to a more distant one, and we will have to make a greater change in elevation to compensate for the drop of the bullet.

The rifleman's rules are: "To *raise* the elevation from one range to a more distant range; or to *raise* the center of impact on the target; *raise* the rear sight. If striking to the left and if it is wished to strike more to the *right;* move the rear sight to the *right*. Move your rear sight the way you wish to move the center of impact. In shooting at any given distance, once you have hit the target, note the location of the bullet hole, and then move your rear sight to bring the next shot into the center of the bullseye according to the rule "one minute equals one inch per hundred yards."

Trajectory Heights

For military cartridges trajectory curves are given to at least a range of 1,000 yards. But for most sporting cartridges it has become the custom of the ammunition manufacturers to give the curves to 300 yards only. Sporting ammunition is commonly used for hunting, the distance to the game must be estimated, and the errors of estimate, plus the errors of aim, rifle, and ammunition are usually such that a hit cannot be assured beyond 300 yards. At least that has been the thought until very recently. But in the last few years new cartridges and better rifles have extended the sure hitting range, and

for some of this new sporting materiel the range tables should now be extended to include 500 yards.

In the appendix will be found tables giving the trajectories of all our military cartridges, and of our common sporting cartridges, including some older cartridges no longer in general use.

It is customary to describe the trajectory curve of various cartridges by giving the height of the curve at mid or half the distance above a straight line connecting the center of the bore at the muzzle with the center of the bullet hole in the target. This line is called the *base line for trajectory*. For example, in the ammunition companies common trajectory tables the trajectory of the .30-06 sporting cartridge loaded with a 180 grain pointed expanding bullet at M.V. 2690 f.s., is described as:

100 yard	trajectory	—height at	50	yards	—0.6	inches
200	"	"	— "	" 100	"	3.0	"
300	"	"	— "	" 150	"	7.0	"

meaning, in the case of the 200 yard trajectory, that the path of the bullet at 100 yards will pass through a point 3 inches above a straight line connecting the muzzle of the rifle with the bullet hole in the 200 yard target. This trajectory is obtained by shooting through a thin paper screen at 100 yards and on to the target at 200 yards. Then a base line from the muzzle to the 200 yard bullet hole is established, and it is recorded on the 100 yard screen where this base line cuts that screen. Measuring up from this latter point to the bullet hole in the 100 yard screen gives the height of trajectory at 100 yards.

As a matter of fact the highest point in the trajectory is not at mid range (100 yards) but at some point a little beyond it (about 110 yards) because the trajectory is not a perfect curve, but rather a parabola. However, the difference between mid range trajectory height and the "summit of trajectory" is very slight, and except at ranges over 500 yards it can be ignored.

The above information given by these common tables is not precisely what the practical field user of a rifle wishes to know about his trajectory. The above .30-06 cartridge is one commonly used for big game hunting, and the hunter usually desires to know, supposing he sets his sights so that the bullet will strike the point of aim at 200 yards, how far the bullet will strike above his *line of aim* at 100 yards, and how far it will drop below that line at 300 yards?

Therefore, based on the above trajectory table we will construct a trajectory curve on a sheet of cross section paper, showing the 300 yard trajectory curve with a height of 7 inches at 150 yards above the base line M—T. Anyone can draw such a curve freehand which will be sufficiently accurate to suffice for all practical purposes, mak-

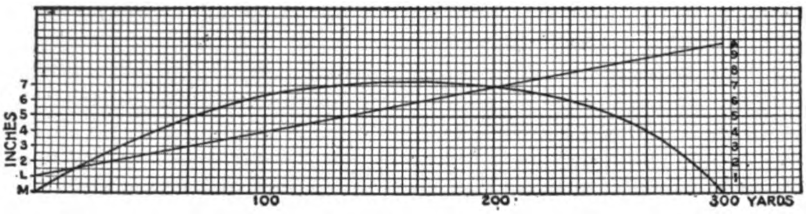


FIGURE 30

Given a .30-06 rifle shooting a 180 grain pointed bullet at M.V. 2690 f.s. Height of front sight 1 inch above the line of bore. To find the trajectory above and below the line of aim when the rifle is sighted for 200 yards:

From the appendix, or from an arms manufacturers catalog, we find that the mid-range trajectory height of this cartridge over 300 yards is 7 inches. This is the height above a line joining the center of the bore at the muzzle (M) with the center of the bullet hole in the target (300).

On a sheet of cross section paper we draw the parabola M—300, making it 7 inches above the base line at the 150 yard vertical line. Then from a point 1-inch above M we draw the straight line L—A intersecting the trajectory curve on the 200 yard vertical line. This is the line of aim. We then obtain the data desired by measuring from the line of aim to the trajectory curve.

Thus we find that the bullet, starting from the muzzle 1 inch below the line of aim, cuts the line of aim at about 25 yards, is 2½ inches above the line at 100 yards, again cuts the line of aim at 200 yards, and drops 9¾ inches below the line at 300 yards.

ing the curve a little less with respect to its radius between 150 and 300 yards than it is between the muzzle and 150 yards as shown in Figure 30.

On most rifles the top of the front sight establishing the line of aim is from .75 to 1.10 inch above the axis of the bore, and the line of aim with a telescope sight is about 1.25 to 1.75 inches above the bore line. We will call this line of aim one inch above the bore, and on the paper we will place a point one inch above the muzzle M, and connect that point L with the point on the trajectory curve where that curve crosses the 200 yard trajectory line. This line L—S will then represent the line of aim which would cause the bullet to strike the point of aim at 200 yards. Now if we measure the vertical distance from this sight line L—S to the trajectory curve we will have a practical trajectory table for field use. The graph shows that if we sight for 200 yards, then the bullet, starting from the muzzle one inch below the line of aim, will cut the line of aim at about 20 yards, be flying 2½ inches above it at 100 yards, will then cut the line again at 200 yards, and drop to strike 9¾ inches low at 300 yards.

Flatness of Trajectory

A trajectory is said to be flat when the curve rises only slightly above the base line or the line of aim. The factors which make for

flat trajectory are high velocity, and good maintenance of velocity by excellence of bullet form. See Figure 31.

A flat trajectory is always an advantage, particularly in a rifle and cartridge that are to be used in the fields of war or sport where the distances are usually not known and have to be estimated with more or less error. And even with a target rifle that is used only at known distances it is an advantage because the attending high

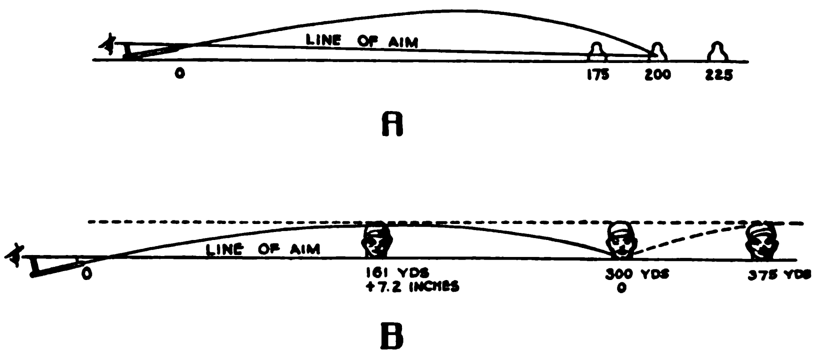


FIGURE 31

A. Disadvantage of a Curved Trajectory. If the distance is estimated to be 200 yards, and sights set accordingly, if the true range happens to be 200 yards or very close to it, the target will be struck. But if an error has been made in the estimate, and the true range is 175 or 225 yards, the target will be missed completely.

B. Advantage of a Flat Trajectory. Battle Sight and Danger Space of Garand Rifle—U.S. Rifle, Cal. .30, M1, and Ball Cartridge, Cal. 30, M2. 150 grain bullet, M.V. 2800 f.s. If the rear sight is set at the Battle Range (300 yards) and aim taken at 6 o'clock on the head of an enemy (as though the head were a bullseye) the head will be struck all the way from the muzzle of the rifle to 300 yards, and beyond up to about 375 yards there is a chance that a ricochet might strike. The summit of the trajectory is 7.2 inches at 161 yards.

velocity and time of flight usually, but not invariably, mean less wind deflection. The factors which limit the flatness of trajectory are pressure, recoil, weight, and barrel life, which must be kept within safe and reasonable limits.

Figure 31A shows the disadvantage of a curved or high trajectory. It is assumed that the distance to the target is not known exactly but is estimated to be 200 yards, and the rear sight has been set accordingly at the 200 yard elevation. If the shooter's estimate was wrong, and the actual distance was either 175 or 225 yards the target will be missed. An error of 25 yards in estimating a distance around 200 yards is quite common and unavoidable.

Figure 31B shows the advantage of a flat trajectory. In this case

the target will be struck all the way from the muzzle of the rifle to 300 yards, with the sight set for that little distance, and up to 300 yards no particular estimate of the distance is necessary.

Danger Space. Formerly danger space with military rifles was calculated under the assumption that the rifle, when fired, was 56 inches from the ground, that it was aimed at a point 34 inches from the ground (an enemy's belt), and that the stature of a man was 68 inches. Accordingly, when the common rear sight (Model 1905) was designed for the Springfield Model 1903 rifle, it was constructed so that when the leaf was laid flat an open sight on the leaf, known as the "battle sight" came into firing position. This battle sight was supposed to be of correct height for a distance of 547 yards, so that if aim were taken at the belt of an enemy he would be struck all the way up to about 650 yards. At 300 yards the man would be struck in the head, at 547 yards in the belt (point of aim), and at 650 yards in the feet.

Such a danger space proved rather unsatisfactory because most targets in battle were no larger than the size of a man's head, and with the sight set at 547 yards, and aim being taken at the head, it would be missed completely by overshooting between the ranges of about 100 yards and 500 yards.

Accordingly when the Garand semi-automatic rifle was designed its rear sight had a battle sight marked on it which was correct for striking the point of aim at 300 yards. With the sights thus set, if the soldier aims at an enemy's head at 6 o'clock as though it were a bullseye, his bullet will strike the head somewhere all the way from the muzzle of the rifle up to 300 yards, and beyond up to about 375 yards there is a good chance for a ricochet glancing into the head. See Figure 31 B. Soldiers are instructed to habitually keep their rear sights set at this battle range. Then if a target is presented suddenly, which almost always occurs at rather short range, and the soldier aims directly at it, he will almost certainly strike it without any delay to make an estimate of the range. If, however, the range is known with fair accuracy, the officer will order rear sights set for that particular range, or in absence of instructions the soldier may so set the sight on his own initiative if there is time. This particular 300 yard battle range is calculated for the present service cartridge, the Ball Cartridge, Caliber .30, M2—150 grain pointed bullet at M.V. 2800 f.s.

Similar battle sight or hunting sight adjustments can be calculated for other trajectories, and for targets of other sizes—for example, hunting sight adjustments for squirrels, woodchucks, deer, or moose, all of which present targets of very different vertical height.

It is thought best here to explain a matter which really comes under the subject of Rifle Marksmanship rather than under Ballis-

tics. Among well trained riflemen in the United States when shooting at known distances and not hurried, the sights are invariably set for that distance, and aim is taken at the bullseye in a normal manner. If everything is correct the bullseye will then be struck in the center. If, however, as most frequently happens, the first shot, or the first several shots strike the target at some little distance from the center of the bullseye, the sights are then adjusted slightly, according to the "minute of angle" system already described, so as to make the center of impact and point of aim coincide. Aim is never taken, for example, slightly higher or lower on the target to correct for shots that might strike low or high.

This is because when continually aiming normally the rifleman has impressed on the retina of his eye a memory of the image or picture of the sights or bullseye correctly alined. With practice he becomes able to duplicate this picture with uncanny accuracy, his aim is thus uniform and accurate, and high scores result. But if he were to aim off, for example try to aim four inches low to correct for shots that were striking four inches high, such holding low would be only an estimate, and the picture would not be the same as that he had been trained to duplicate with accuracy. Hence the accuracy of shooting would not be nearly so good, and scores would suffer. In known distance target shooting there is almost always time to adjust sights and to correct adjustments in the above manner.

But in close warfare and in hunting the range is scarcely ever known exactly, and there is seldom time to adjust sights for the estimated range. Indeed there may be no time to estimate the range. Hence the soldier and the hunter habitually carries his rifle with the sights set for a "battle range" or a "hunting range," which will give him a trajectory curve flat enough so that the target aimed at will surely be struck either at the muzzle, or all the way up to the maximum distance practical with that trajectory. In Figure 31B this sight setting and the maximum range for a target the size of a man's head is seen to be 300 yards.

Cartridge, Carbine, Caliber 30, M1 Trajectory. This is the cartridge used in our small Army semi-automatic carbine. The round nosed, gilding metal jacketed bullet weighs 110 grains and the muzzle velocity is 2000 f.s. For military purposes, for which alone this carbine is suitable, it will perhaps be most advantageous to set the new adjustable rear sight (or to alter the height of the front sight on carbines having non-adjustable sights) so as to strike the point of aim at 200 yards. In round figures the bullets will then average striking above the line of aim—2 inches at 25 yards, 3 inches at 50 yards, 5 inches at 100 yards, and 3 inches at 150 yards. The carbine is supposed to be effective to 300 yards, and that is the maximum range to which it is sighted. But experience has shown that its effec-

tiveness and ability to hit with it decrease considerably beyond 200 yards.

.22 Rim Fire Trajectory. Let us make a short study of the trajectory of a few of our representative cartridges. We have already done so with our chief military cartridges. Suppose we start with the cartridge that has the most curved trajectory of all, the small but very popular .22 Long Rifle cartridge. From the standpoint of small bore rifle shooting, that is known distance firing, we are not particularly interested in its trajectory, but only in its accuracy. But this cartridge is widely used for small game and small varmit shooting, all

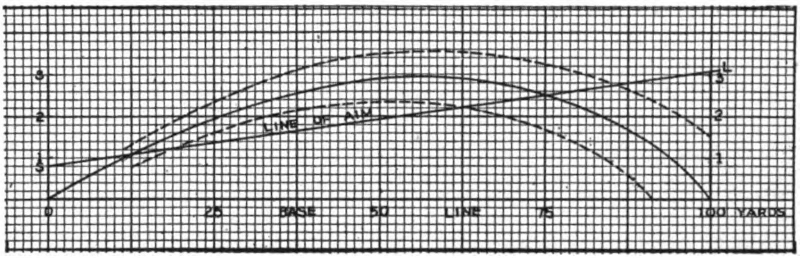


FIGURE 32

Trajectory of the .22 Long Rifle High Velocity Cartridge. When the rifle is sighted for 75 yards the bullet will strike or fly one inch above the line of aim at 40 yards, and drop three inches low at 100 yards, on an average. The dotted curves show the sheaf of fire within which all the bullets can be expected to pass.

at more or less estimated distances. Such targets are very small, and here trajectory becomes of vital importance for the reason shown in Figure 31.

For the purpose of hunting we will choose the high velocity cartridge because it has a flatter trajectory than the regular .22 Long Rifle cartridge. The ammunition companies trajectory table (see Appendix) shows the Winchester Super Speed .22 Long Rifle Cartridge, 40 grain bullet, M.V. 1375 f.s., to have a trajectory height above base line of 2.9 inches at 50 yards when fired over a range of 100 yards. On a sheet of cross section paper we will lay out this trajectory curve as shown in Figure 32, solid line.

The smallest game which we will probably wish to hunt with a rifle for this cartridge is the gray squirrel which has a diameter of head, and also of the vital parts in the chest area of about two inches. For our hunting trajectory we would therefore prefer one which, when the aim is taken at the center of the head or chest, will not pass more than an inch over or under the line of aim. We will assume that the front sight on our rifle is .75 inch above the axis of the bore. Therefore we will draw the line of aim S—L from a point .75-inch above the muzzle point o to intersect the trajectory at 75

yards. The trajectory curve at 40 yards, as will be seen, is one inch above this line of aim. Thus, measuring vertically from the line of aim to the solid trajectory curve we see that if we sight our rifle to strike the exact point of aim at 75 yards the bullet will average cutting the line of aim at 12½ yards, hit one inch above it at 40 yards, cut the line of aim again at 75 yards, and drop below the line of aim about one inch at 85 yards, and three inches at 100 yards. Therefore with perfect aim and an accurately flying bullet, with no error, we should kill our gray squirrel every shot up to 85 yards.

But of course this is not strictly true because even with perfect aim every bullet will not fly perfectly true along the trajectory line. Indeed, using the very best .22 caliber sporting rifles and the high velocity cartridge of best present manufacture the smallest extreme spread that can be expected from a group at 100 yards is 3 inches. Therefore we will draw two dotted curves from the muzzle point o, paralleling the trajectory curve, which will have a spread of 3 inches at 100 yards. The area between these two dotted curves is the *"sheaf of fire"* or *"cone of dispersion,"* or the area in which we can be quite sure the bullet from a perfectly aimed shot will strike. This sheaf terminates one inch vertically above the line of aim at about 27 yards. Therefore, with this sight adjustment 27 yards is about the maximum distance at which we can be absolutely sure of striking our gray squirrel in a vital spot.

If we wished to use our rifle exclusively for squirrels we could sight it for 50 yards instead of 75 yards, and on that basis we could project another line of aim which would show that our sure hitting distance on the squirrel had been extended to about 38 yards. Or, using one of the super-accurate match varieties of the .22 Long Rifle regular velocity cartridge, which will give an extreme spread of only about 2 inches at 100 yards, the sheaf of fire would be so reduced that, sighted for 50 yards, we could be assured of a hit on a squirrel up to 50 yards.

But when we are out hunting with this rifle we might also expect to get shots at crows or other small game. A crow presents a vital target about three inches in diameter. If we center a 3-inch vertical line on the trajectory curve and run it along our graph we will see that the sheaf of fire is included within it all the way up to about 80 yards. Therefore with perfect aim and trigger squeeze we should hit our crow every shot up to 80 yards.

We therefore see from this study that for general hunting it is perhaps best to use the high velocity cartridge, and sight our rifle for 75 yards. Then we have a sure hitting range on squirrels to 27 yards, and on crows and similar size game to about 80 yards, and within these distances we will not have to estimate the range or allow for the fall of the bullet. And, by aiming a couple of inches high we

would have an excellent chance of hitting a large hawk at 100 yards, provided we knew that the distance was very close to that distance. But beyond 100 yards the curved trajectory and the error of estimating distance make it all guess work with this cartridge, the misses usually greatly exceeding the hits.

.22 Hornet Trajectory. The .22 Hornet cartridge shooting a 46 grain bullet at M.V. 2600 f.s. has a much longer sure hitting range on small game and varmints than the .22 Long Rifle cartridge, and being much more powerful it is entirely satisfactory for game as large as woodchucks and foxes. Also in a good rifle it is a very accurate cartridge, the extreme spread being only about 1½ inches at 100 yards. A study of its trajectory and accuracy similar to the above will show that if the rifle be sighted for 150 yards with a telescope sight 1¼ inches above bore line, the bullet will strike one inch above the line of aim at both 50 and 100 yards, and will drop one inch at 175, and 4 inches at 200 yards.

"The proof of the pudding is in the eating." This .22 Hornet cartridge has been used for crow, woodchuck, and other small varmint shooting by thousands of sportsmen, hundreds of whom are really good rifle shots. The consensus of opinion is that it is absolutely sure under almost all conditions on crows to 100 yards, and on woodchucks, which offer a much larger target, to about 175 yards. Beyond these distances the trajectory curve, dispersion of the bullet, error in estimating distance, and wind deflection when wind is present make sure hits rather uncertain.

.22-3000 Lovell R2 Trajectory. In good rifles and with best bullets this remarkable little cartridge has a flatter trajectory and better accuracy than even the .22 Hornet cartridge, and therefore an extended sure hitting range. One informal test that the writer made in September 1941 will perhaps serve to illustrate its combination of flat trajectory and fine accuracy as well as an extended study. The hand load was 15.5 grains of du Pont No. 4227 powder, and the 47 grain Wotkyns Morse 8S bullet (See Volume I). The rifle was sighted so that the bullet would strike one inch above the point of aim at 100 yards. The target (see Figure 33) was a cardboard silhouette to represent a woodchuck, but made about half size, that is 9½ inches high. This target was set up at 100 yards and ten shots were fired at it, the aiming point being the little black bullseye. This resulted in a group with an extreme spread of 1.3 inches, the center of impact being .95-inch above the point of aim. The silhouette was then moved back to 200 yards, and another group of ten shots were fired with the same aim and sight adjustment. This group is only 1.5 inches below the point of aim and the extreme spread is 2.3 inches. Rifles for this cartridge are all custom made, and the barrels are usually fairly heavy, which to some extent accounts for the fine

accuracy. Cartridges are hand loaded, and the excellent 8S bullet is still more of a factor in obtaining a small spread. Many hundred

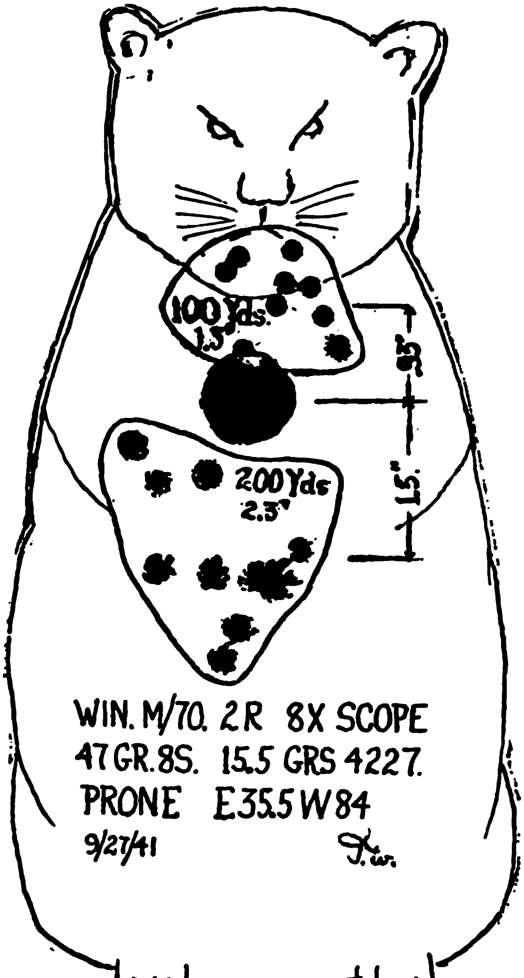


FIGURE 33

The hunting trajectory of the .22-3000 Lovell R2 cartridge. Ten shots at 100 yards, and then ten shots at 200 yards with the same sight adjustment and aim at center of black paster. Rifle was sighted with 8 power Lyman Junior Targetspot scope, the elevation being 35.5 half minutes and the windage 84 half minutes, so as to strike one inch above the point of aim at 100 yds. The target was the cardboard silhouette of a woodchuck reduced to 9½ inches high, and shows the size of the groups, and the rise of the bullet at 100, and drop at 200 yards. The load was 47 grain Wotkyns-Morse 8S bullet, 15.5 grains du Pont No. 4227 powder and Winchester No. 116 primer.

varmint shooters who are fine rifle shots have adopted this cartridge, and their concensus of opinion is that it is sure on crows to 150 yards, and with a little holding over for the longest distances, for woodchucks, jack rabbits, and large hawks to about 250 yards. Furthermore, it has the advantage of giving a light report so that its use in farming country is not usually objected to.

.220 Swift and .22 Varminter Trajectories. If we wish to obtain the longest sure hitting range on varmints, then we have to go to cartridges of extremely high velocity such as these two. The rifles must be well made, they should have at least medium heavy barrels, and of course a telescope sight must be used. We must also use an extremely accurate bullet, the best at present being the Wotkyns Morse 8S bullet of 55 grains. (It is of course impossible to predict what will be the most accurate bullet in post-war manufacture.) With the hand loads that best combine flat trajectory with gilt edge accuracy, the muzzle velocity of the Swift is about 3900 f.s., and the Varminter about 3800 f.s. With telescope sight set to strike point of aim at 250 yards, the bullet strikes about 1¼ inches above the line of aim at both 100 and 200 yards, and drops about 3 inches at 300 and 15 inches at 400 yards. The consensus of opinion is that such rifles are sure on crows to 200, and on woodchucks to 325 yards. But it takes a highly skilled rifleman with a rather complete knowledge of rifle marksmanship, hand loading ammunition, and interior and exterior ballistics to make a large proportion of hits at these extreme ranges.

.30-30 and .348 Winchester Trajectory. We now turn from a consideration of varmint and small game cartridges to those suitable for big game shooting. Over a range of 200 yards the .30-30 cartridge with 170 grain bullet, and the .348 Winchester cartridge with 250 grain bullet (the best weights of bullets from the standpoint of reliable killing power), both have a 100 yard trajectory height of about 4.5 inches. This trajectory, which is apparently rather curved, is yet flat enough for all practical purposes, and nothing would be gained with these two or similar cartridges by any increase in velocity or flatness of trajectory.

We may assume that the vital area over the heart, shoulders, and chest cavity of a deer is roughly represented by a circle ten inches in diameter. Both of these cartridges are adapted only to lever action rifles, the accuracy of which is decidedly limited as explained in Volume I. Also the particular rifles adapted to these cartridges are not suitable, by reason of their top ejection, for telescope sights. Long and extended experience has shown that the errors of rifle, cartridge, aim, and estimate of distance are such that, excluding errors of marksmanship, a 10 inch target cannot be surely struck at a much longer distance than 150 yards. These rifles had best be

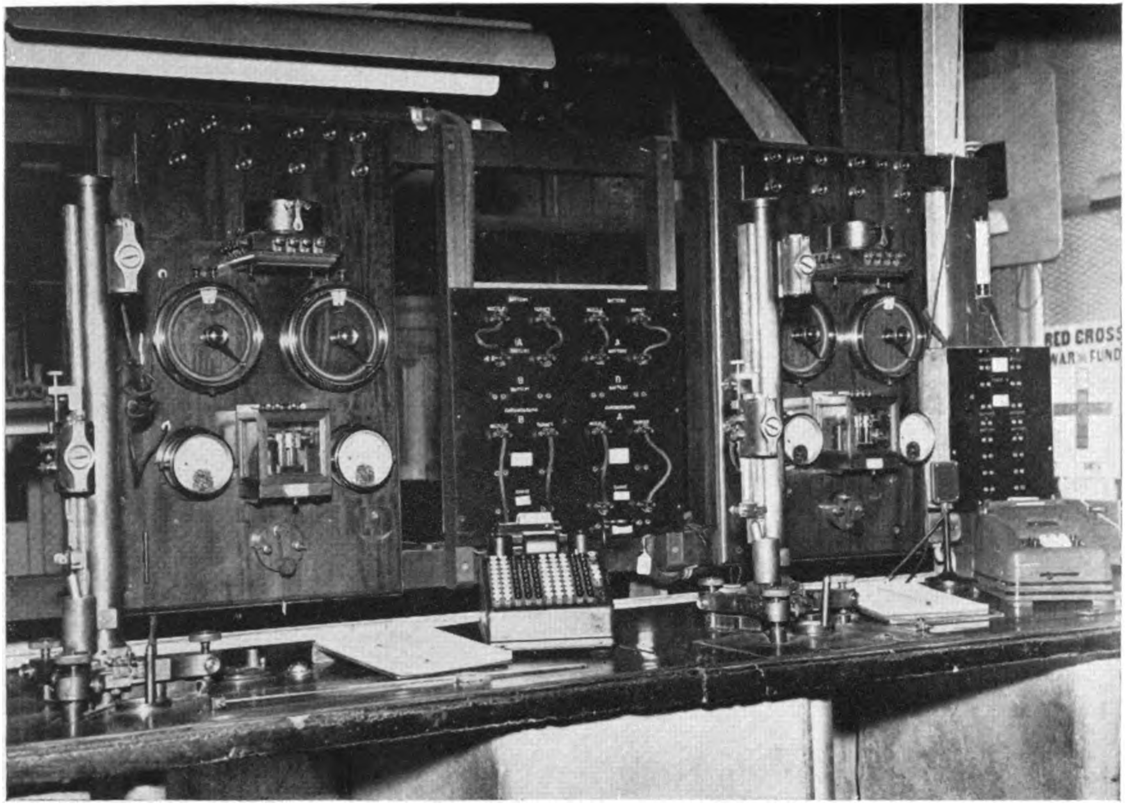


Figure 13

Two Le Boulenge chronographs installed on bench in the ballistic laboratory of the Remington Arms Company, showing the two pillars, each with their two magnets. The upper ends of the two rods are shown projecting from their boots.

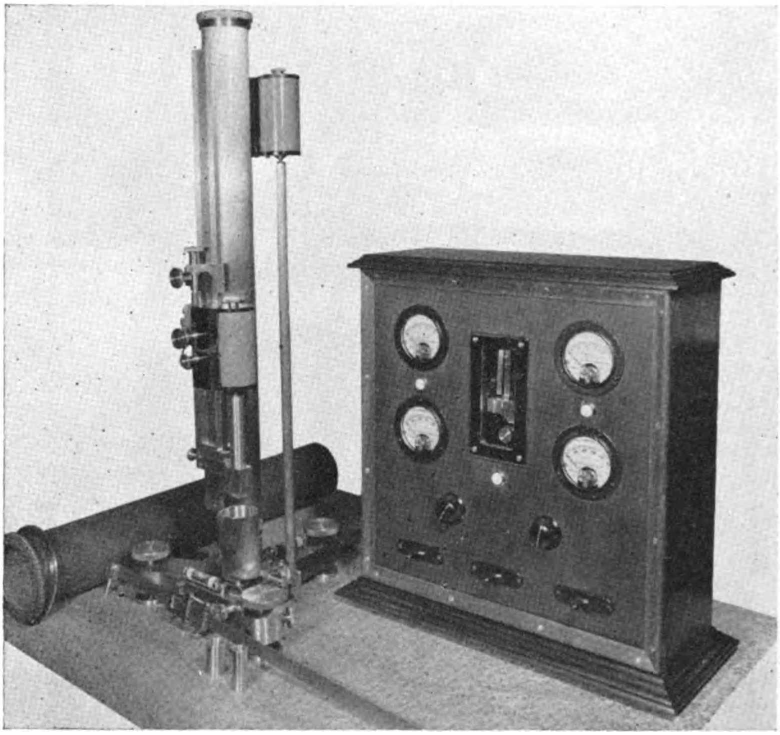


Figure 14
A modern type of the Le Boulenge Chronograph as supplied by the Modern-Bond Corporation to plants manufacturing military ammunition for use in World War II. Courtesy of Modern-Bond Corporation.

sighted for 100 to 125 yards. A further study of these trajectories is therefore unnecessary.

.270 Winchester Trajectory. Here we come to what the writer believes to be the most interesting of all American rifle cartridges from both a military and sporting standpoint. It has never been adopted for military purposes, although it would seem to qualify for such use to an eminent degree. It combines very flat trajectory, excellent accuracy, light recoil, and adaptability for almost any purpose by hand loading. It has sufficient killing power for any American game. The bullet which is the most interesting one is that weighing 130 grains, which normally is given a muzzle velocity of 3120 feet per second.

For this 130 grain bullet the ammunition companies trajectory table gives mid-range trajectory heights of two and five inches over 200 and 300 yard ranges. But for a proper study we should have a 400 yard trajectory curve, which is not given in these tables. We can, however, easily construct such a curve from the Table of Angles of Elevation given in the appendix. These angles are; 200 yards, 2 minutes; 300 yards, 3.5 minutes, 400 yards, 6 minutes, and 500 yards, 10 minutes. If we were shooting at 200 yards and averaging striking in the center of the bullseye, then, according to this table, we would have to raise our rear sight four minutes to strike center at 400 yards. Four minutes at 200 yards equals eight inches. Therefore over a range of 400 yards the trajectory height at 200 yards is eight inches.

With a scope sight height above bore of 1.3 inches we draw the Line of Aim L-A intersecting the trajectory curve at 250 yards. That is, our rifle is sighted to strike the point of aim at 250 yards. We then see on the graph, Figure 34, that the bullet will strike 2¼ inches above the point of aim at 140 yards, and drop below 2¼ inches at 300, 6 inches at 350, and 11½ inches at 400 yards. On a deer we would make no attempt to estimate the distance and allow for the trajectory at what we thought in our hurry to get in a shot was less than 300 yards, but would just aim at the point marked "AIM" on the deer target. This point is approximately the center of the deer's heart. If the deer was standing facing in some other direction we would still aim for this point through whatever part of the anatomy might intervene. With this aim at various distances the bullet will strike at about the points indicated on the deer target. At over 300 yards we would probably have a little more time to estimate the distance. A hurried estimate in the hunting field is far from accurate. About all we could do in the short time, and under more or less excitement, would be to decide that the deer was somewhere between 300 and 400 yards. If we thought it was over that distance we should not fire. But at what we thought was between 300 and 400 yards we would aim at the point marked "HOLD

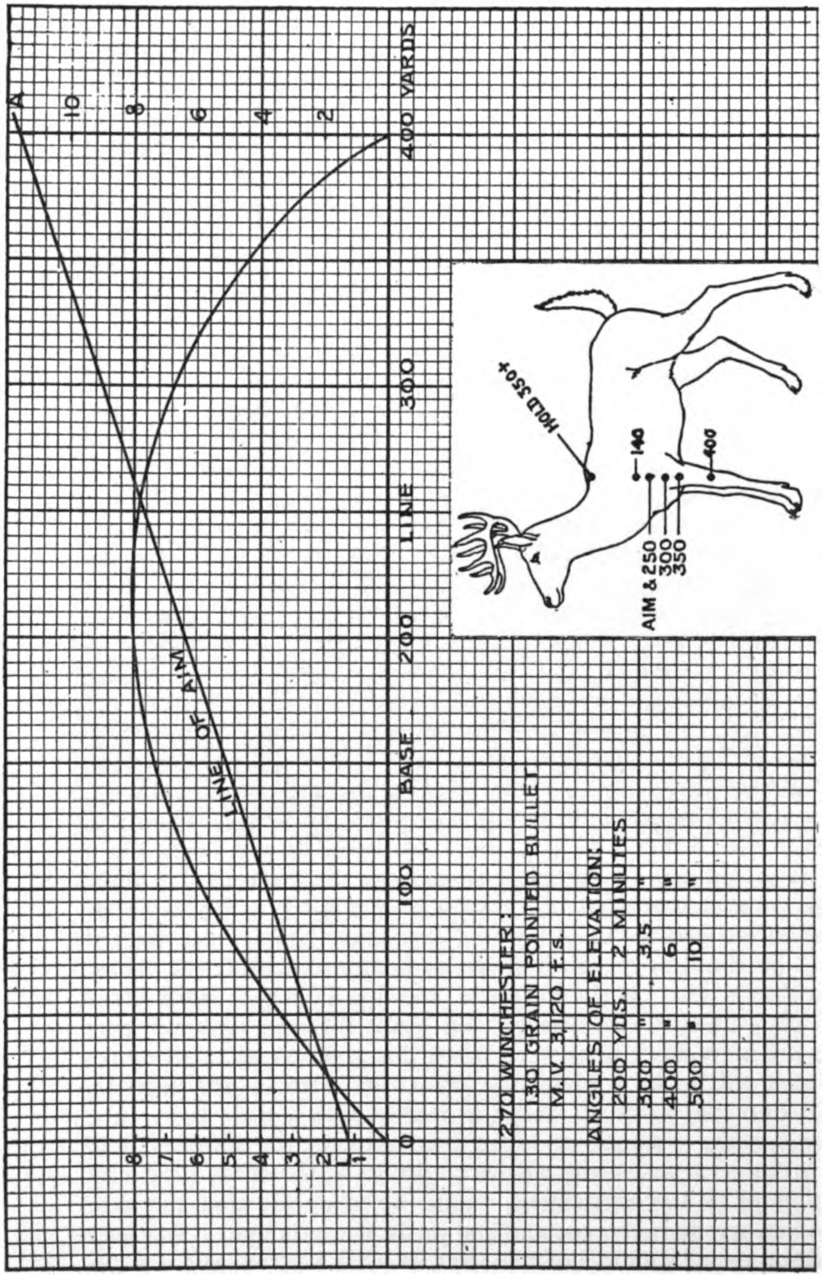


FIGURE 34

Hunting Trajectory of the .270 Winchester Cartridge, 130 grain bullet, showing that with the rear sight set for 250 yards the sure hitting range on deer and animals of a similar size is approximately 350 yards. See text.

350+." The bullet would then strike well into the chest cavity which is a very vital region, except that at 400 yards, where the extreme spread of rifle and ammunition is about 8 inches, approximately 25 percent of the bullets might miss the deer just under the chest, so that at a full 400 yards our chance of a vital hit is about 75%.

We can therefore make a simple rule, easy to remember, to guide us when hunting with this rifle and cartridge. "Up to what we think to be not over 300 yards, aim directly for the heart region. If we believe the animal is beyond 300 yards, aim at the top edge of the animal above the heart area." Then, if we do our part correctly, we can be sure of a hit in a vital part to 350 yards at least. We therefore say that this rifle and cartridge, when sighted for 250 yards, and with just a little holding over at the longest distances, has a sure hitting range of 350 yards on deer.

In the above we have assumed that the height of the chest cavity on the average buck is about 15 inches. On larger animals the sure hitting range would be slightly extended. On elk and moose it would probably be around 400 yards with the same sight adjustment and rule. But we wish to kill cleanly as well as hit, and at 400 yards the remaining velocity and killing power of this 130 grain bullet would be so reduced that it might not kill well on elk and moose. So we had better count on the sure hitting and killing range on all American big game animals as being 350 yards.

On coyotes the height of the chest cavity is only approximately six inches. Here we do not need the heavier 130 grain bullet to kill, and we might use the 100 grain bullet which, in the .270 cartridge has M.V. 3540 f.s. with a 200 yard trajectory height of only 1.5 inches, or about one inch over the line of aim when sighted for 200 yards. With a similar study on cross section paper we would probably find that the sure hitting range on this small animal was about 300 yards and here is another instance and range where it will take considerable skill and the best of equipment to make many such hits.

Point Blank Range

This is a term applied in the past to indicate the distance over which the trajectory of a bullet was so flat that no allowance for distance or the drop of the bullet was necessary. Theoretically there can be no such thing as a point blank range because the bullet starts to drop as soon as it leaves the muzzle. Practically, however, there can be such a range if the term is qualified by stating the size of the target it is to apply to. Thus we have seen that for the .22 Long Rifle cartridge and for a squirrel's head, 27 yards might be called the point blank range, and for the .30-06 service cartridge and an enemy's head it might be said to be 300 yards. But the term is misleading, it infers that there is a distance over which the bullet flies

perfectly flat, and hence we prefer to use the terms "hunting range" or "battle range."

Zero

The "zero" of a rifle, or the "zero sight adjustment," is that adjustment of the rear sight in elevation and in windage or azimuth which, at a given range, will cause a properly aimed shot to strike the point of aim, or in some cases the center of the bullseye.

From a purely ballistic standpoint the zero of a rifle is that reading on the rear sight scales which will occur when the line of aim and line of departure are parallel both vertically and horizontally. It is usually obtained by firing the rifle at a target placed 12½ yards from the muzzle, and adjusting the sights until the bullet strikes below the point of aim a distance equal to the height of the sights above the axis of the bore plus the amount the bullet would drop over the 12½ yards from the force of gravity. This zero is then the starting point from which angles of elevation, wind deflection, and drift are calculated.

Ballisticians have always used a zero obtained in this or a similar manner, and it is the true zero. But from a practical point of view there are some objections to using a zero established in this manner, and this work has been prepared from a practical viewpoint. That is, the writer has assumed that the chief reason for a study of Small Arms Ballistics is to enable the shooter to *hit*. The objections to using the true zero are that comparatively few rifles and sights are so constructed that the rear sight can be depressed sufficiently to determine a zero setting at 12½ yards or closer, and a bench rest and extreme nicety are required for such a determination where even one fourth of the diameter of the bullet hole will be an appreciable error in point of impact.

In actual practice the small bore riflemen and those using .22 caliber rim fire rifles, or rifles taking cartridges having a muzzle velocity of less than 2000 f.s., determine their zero or basic sight adjustment at 50 feet, because in usual practice that is the shortest distance at which they will ever be called upon to use their rifles.

Those riflemen who use weapons with a muzzle velocity in excess of 2000 f.s. have similarly been accustomed to determining their zero of basic sight adjustment at 100 yards, because at that distance the trajectory is practically flat considering the size of the target on which such rifles are used. Also, one hundred yards is a most convenient distance because a safe range of that length can usually be obtained in any farming country, and at that distance the location of the bullet holes in the target can be seen from the firing point with the aid of a spotting telescope, and no marker, elaborate target carrier, or shelter at the butt is necessary.

Therefore throughout this work, and in the tables of angles of elevation in the appendix the writer has preferred to use the elevation which will result in striking the point of aim at 50 feet as the zero for .22 caliber rim fire cartridges, and 100 yards for all other cartridges. The ballistician can readily correct his calculations and tables to a true zero reading if he so desires.

The first thing a rifleman must do, therefore, when he takes up a new rifle, or a strange rifle, is to determine its zero, or in more common terms, sight the rifle in for the shortest distance at which he will commonly use it. He must do this with the ammunition he intends to use with it, or separately for all the loads he intends to use, for the zero will differ with every variation in load because of the variation in trajectory, jump and vibration. Moreover the rifleman must do this himself, he cannot employ another to zero the rifle for him, because the other person might not hold the rifle the same or with a similar tension, and might not aim it the same or have similar eyesight. The jump, vibration, and line of aim would be different, and hence the zero for individuals will usually vary, sometimes considerably. For this reason rifles zeroed at the factory will seldom be correct for any one individual. Skill in marksmanship is therefore a pre-requisite for zeroing.

(During World War I an experiment was made with two riflemen of international reputation. They were given the same rifle, same sight adjustment, asked to assume the same firing position, and aim normally at a target at 100 yards. Their centers of impact were five inches apart! With two members of the Army Infantry Rifle Team, all conditions being the same except tension of hold and eyesight, centers of impact varied 11 inches vertically and 4 inches horizontally at 200 yards.)

As the writer is penning these words, individual trained Infantrymen are being sent abroad to fill vacancies occurring in organizations on the fighting fronts due to the killed, wounded, missing, and invalids. When these individual replacements arrive abroad and in rear of the battle front, and before they actually join their new units on the battle line, each soldier: "is given his weapon, *an opportunity to zero it in and the chance to familiarize himself with it,* is issued a gas mask and provided with opportunity for testing it; and worn, ill-fitting, and unserviceable clothing is replaced." Without the opportunity to zero his weapon a replacement would be useless on the firing line, for he would not hit what he aimed at.

In zeroing a rifle at any range, (except for the true zero at 12½ yards) the rifleman usually fires, either from a bench rest with the center of the firearm resting on a soft pad, or from a sandbag rest, or in the prone position with the gunsling. He continues to fire, and to make any needed adjustment on his rear sight, until at that distance

his center of impact (center of group) coincides with the point of aim. He then makes a record of this sight adjustment, setting down also other pertinent data such as rifle number, type of sight, ammunition, light, temperature, and wind. This zero then becomes the basis from which all further adjustments are made.

With military rifles (except the U.S. Rifle, Cal. .30, M1-Garand) having rear sights graduated in yards, and with a fixed windage zero, this determined zero may not agree with the markings on the sights. In that case the soldier computes all his elevation and windage allowances from his determined zero and not from the formal markings on the sights.

With the best hunting and target sights now fitted to sporting and match rifles, the zero markers or indexes for both elevation and windage are on plates that can be moved with a screwdriver, so that, having determined the zero, the plates can be moved to correspond so that the scales will read zero.

In the case of a rifle having an open post or bead front sight, and used exclusively for target shooting, aim is not taken at the center of the bullseye, but with the top of the front sight just touching the bottom of the bullseye at 6 o'clock. Then the rear sight is adjusted until the bullets average striking the center of the bullseye. That is the rifle is zeroed to strike high by half the diameter of the bullseye instead of being zeroed to strike point of aim.

With the U.S. Rifle, Caliber .30, M1-Garand, the rifle is zeroed at 200 yards for known distance target firing on the military target A (bullseye 10 inches in diameter) in the following manner:

1. Set the elevation at 15 clicks up from the lowest elevation to which the elevating knob can be turned; set the windage at 0 in the normal manner. Fire a group of two or more shots and apply corrections in elevation and windage to bring the center of the next shot group or groups into the center of the black bullseye 5 inches above its bottom. Do not change the sight setting which obtains this result.

2. Being careful not to disturb the above sight setting, loosen the screw in the elevating knob with the srewdriver blade of the combination tool. Pull the elevating knob away from the receiver until its teeth are completely disengaged, and then set the 200 mark on the drum exactly opposite the index line on the sight base.

3. Tighten the screw. The rifle now has its sight set exactly at 200 yards, and is also correctly zeroed for 200 yards in elevation. Record the windage correction in the score book. Unless the rifle is subjected to especially hard usage, the sight setting of exactly 200 yards in future will be the zero elevation for that range. Minor adjustments in elevation to compensate for light on different days may be applied as clicks. These should be recorded in the scorebook.

Turning now to the Table of Angles of Elevation in the appendix. Suppose we are using a rifle for the .257 Roberts cartridge, 100 grain pointed expanding bullet at M.V. 2860 f.s., and that the rifle has a rear sight adjustable in minutes. We zero it at 100 yards on a bench rest with the forearm resting on a soft rubber pad. Having obtained the correct zero adjustment we move the elevation index plate so that the elevation scale reads zero, and we similarly move the windage index plate (provided we were shooting on a day when no wind was blowing.) Then from the table of angles of elevation we will see that the 200 yard elevation will be 2.5 minutes, 300 yards 5.7 minutes, 400 yards 9.6 minutes and 500 yards 14.3 minutes. If we decide to prove this out by firing at these ranges we will probably find that the elevations above as given in the table will in no case be more than a minute in error at any distance, and this difference will probably be due to the tension of that particular firing position affecting the jump and vibration for that particular shooting, and not to variation of rifle and cartridge from the table.

As a further measure, looking to learning our rifle more thoroughly, suppose, after zeroing it on the bench rest in the above manner, we lie down and with that zero adjustment fire at 100 yards in the prone position with the gunsling. It would be quite common to find the rifle shooting one to two inches low in this position at 100 yards for the reasons given in Chapter IV. Then we would know that in firing it at this distance prone with the gunsling we would need to add one to two minutes to the zero adjustment, and also when firing it at longer ranges we would have to add a similar amount to each adjustment given in the table of angles of elevation.

Importance of Accuracy

We find a tendency among many beginners to choose their cartridge entirely for its flatness of trajectory, or to place too much emphasis on the flatness of trajectory. As a matter of fact, accuracy is of much more importance for we can often make up for a curved trajectory by a little more care in estimating the distance, but if our bullet will not reliably strike where we aim the rifle we cannot hit reliably. While a flat trajectory is a great advantage over long estimated distances, it is not nearly as important from a sporting standpoint as most beginners think, because 90 per cent of all American big game is shot within 150 yards, at which distance even a very curved trajectory is ample.

There is one particular case which completely illustrates the point. The .219 Zipper cartridge, which fires a 46 grain bullet at M.V. 3390 f.s., has all the characteristics of an excellent long range varmint cartridge, although it is decidedly not suitable for any big

game. Varmints present small targets, often at a considerable range, and fine accuracy is needed to hit. An experienced varmint shooter would have no use for any rifle and cartridge that would not group steadily in 2 inches at 100 yards. If it would group in 1½ inches and had M.V. 3390 f.s., then he would feel quite sure of hitting crows to 150 or woodchucks to 225 yards with it. The .219 Zipper cartridge, in a well designed bolt action rifle custom made for it, will do this. But the only rifle that is commercially and regularly made for this cartridge is a lever action arm of light weight. We have already seen in Volume I that the average extreme spread at 100 yards that can be expected from such a rifle and with iron sights which alone are adapted to it, is about 3½ inches. Anyone who favored the flat trajectory of the Zipper cartridge, and who selected one of these lever action rifles for it, would be sadly disappointed if he were to attempt varmint shooting with it.

The trouble with the beginner is that he takes accuracy for granted. The only sure proof is an accuracy test with the weapon and cartridge. A record of what a certain model and caliber of rifle has done is not sure proof that another quite similar weapon will do the same. However, the chance of getting a poor weapon diminishes in the case of certain modern types. If the shooter will select a first class modern bolt action of fair weight, and by a reputable manufacturer, in a seasoned stock and with good sights, and in a caliber noted for fine accuracy, he will run about a 95 percent chance of obtaining a weapon of fine accuracy. And if he will take a little trouble to experiment with various makes of cartridges or loads for it, particularly as to the bullet used, the chances are he will obtain gilt edge accuracy. If he does not, the places to look first for the trouble are in the bedding of the rifle in its stock, and the bullet.

To evaluate any combination of trajectory and accuracy, make a graph of its trajectory curve and cone of dispersion on cross section paper* as shown in the preceeding graphs. Consider that errors of as much as 20 percent are frequent in estimating the range, prepare an averaged size target to the scale of the graph and run it along it, and you will obtain a very reliable indication of the value of rifle and cartridge in probability of hitting the target in a vulnerable spot.

Books on big game shooting in the English language are legion. Several hundred of these have been written by sportsmen who have had vast experience all over the world, not merely having shot a

* Sheets of cross section paper, 8½ x 11 inches in size or larger, may be obtained from dealers in artists and draftsmans supplies. Ask for squares ruled in "twelfths," if you want to figure out in feet and inches, or "tenths" if you want to figure in hundreds of yards.

dozen or so animals and then rushed into print, but rather writers who have spent a whole lifetime at the sport, and who have shot hundreds of animals of many species under all sorts of conditions.

Fifty years and more ago, when black powder was the only propellant, it used to be the fashion among all such authors to include in their books a chapter on "Advice to Young Sportsmen." These chapters invariably contained the caution that 150 yards was the maximum distance at which a shot should be taken at big game. This from the standpoints of hitting, killing, humanity, and good sportsmanship. Let us analyze this statement and see what the facts are.

In black powder days a very common cartridge, considered suitable for all big game except elephant, rhinoceros, and African and Asian buffalo, was the .45-90-300. It shot a 300 grain bullet at M.V. 1480 f.s., and the height of trajectory at 100 yards when shooting at 200 yards was 10.25 inches. We therefore place this trajectory on cross section paper. See Figure 35. But we also wish to include the cone of dispersion so let us see how accurate this cartridge was.

In his younger days the writer did a large amount of experimenting with black powder game rifles in an effort to obtain the finest accuracy from them. In those days he had skill in marksmanship necessary to win a place on a number of national rifle teams. Only black powder cartridges of .45 caliber and over were considered suitable for all around big game shooting. With cartridges of that caliber, shooting lubricated lead bullets, and with bullets seated to normal depth in the case, he never obtained a better average than six inches extreme spread at 200 yards. In those days there were no telescope sights suitable for big game hunting, so to this spread we must add an error of aim which amounts to about 2 inches at 200 yards, so we lay out the dotted lines indicating such a cone of dispersion on the graph. We also set down the line of aim to intersect the trajectory at 100 yards. See Figure 35. It was common practice in black powder days to sight hunting rifles for 100 yards.

We now see from our graph that sighted for 100 yards some of the bullets would strike 2¼ inches, and some only ⅞ inch high at 50 yards. At 150 yards some would strike 4 inches low and some 8½ inches low, while at 200 yards some would strike 15 and some 24 inches low. If the animal was estimated to be 200 yards away, and the rear sight was set at 200 yards, but the true distance proved to be only 150 yards, some bullets would strike 11 inches high, and some only 7 inches high. Any shot striking about 5 inches too high or low would usually miss the vital part of the animal. Truly the old hunters were not far wrong when they assigned 150 yards as the hunting range for black powder rifles. A comparison of this graph with that for the .270 cartridge in Figure 34 will show how the improvements of fifty years have extended the hunting range.

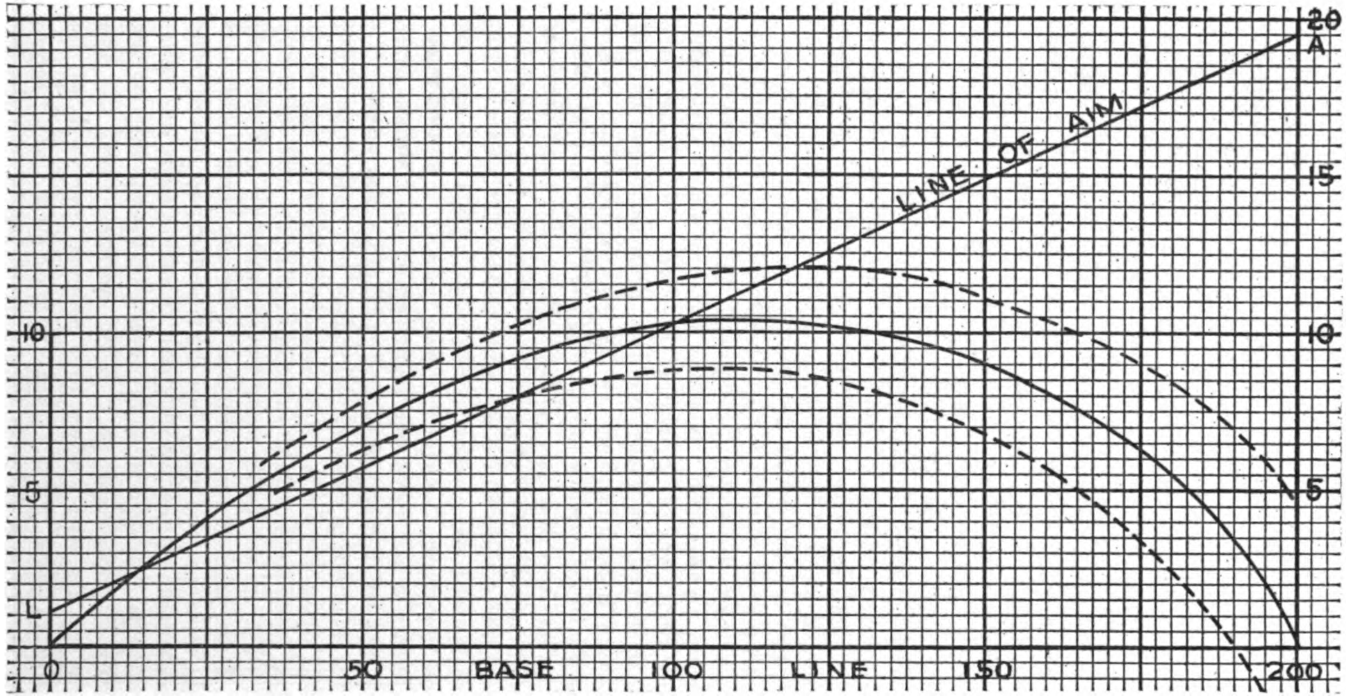


FIGURE 35
Trajectory and accuracy of the .45-90-300 black powder cartridge. 300 grain lead bullet, M.V. 1480 f.s. Rifle sighted for 100 yards. Showing that the practical sure hitting range for big game was about 150 yards. Vertical dimensions represent inches, horizontal dimensions represent yards.

The late Captain Edward C. Crossman gave the following reasons why high velocity and flat trajectory contributed to practical accuracy when the pure accuracy of two cartridges was the same:

1. The penalty for canting the rifle—rolling it on its long axis—is much reduced with a high velocity, flat trajectory rifle.
2. Small variations in velocity mean much less in vertical error at the target, due to the flatness of the trajectory.
3. The bullet escapes from the rifle before the greater barrel vibrations have a chance to assert themselves.
4. Wind effect is much less—unless the bullet is very light and deficient in shape and ranging ability.
5. The lead necessary to hit moving game is much less because of the lesser time of flight.
6. The trajectory is more nearly flat and the space over which it will strike a vital area is longer.
7. The barrel time is less and the chance for a movement of the rifle by the shooter after releasing the trigger is reduced.
8. Smaller variations are caused by temperature changes.*

Effect of Temperature, Barometer, and Altitude

A rise in temperature above normal slightly increases the velocity, with a corresponding flattening of the trajectory. If the temperature is high, less energy is required from the primer to raise the temperature of the powder to the ignition point, and warmer powder burns faster. Low temperatures work in just the opposite direction. Normal temperature is assumed to be 70° F, and all velocities, pressures, and trajectories are taken at approximately that temperature unless otherwise stated.

As a very rough rule, riflemen have assumed that a change of 1° F in temperature will cause a change of 1.5 f.s. in velocity, and that with muzzle velocities around 2700 f.s. a change of 20 degrees in temperature will so alter the trajectory as to necessitate a change of one minute in sight adjustment. This is by no means infallible.

The effect of temperature is apparently greater with double-base powders which contain nitro-glycerin and nitro-cellulose, than with single base powders containing nitro-cellulose alone. When cartridges are loaded with a double base powder a smaller charge has to be used for tropical climates than for temperate regions in order to maintain the sighting of the weapon.

Metallic rifle cartridges are now commonly loaded with single base powders. With high intensity and high power rifle cartridges the loss in velocity due to a change in temperature from plus 70 degrees to minus 40 degrees F has been found to be from 3 to 5 percent.

* "Military and Sporting Rifle Shooting," page 202.

With revolver cartridges from 5 to 8 percent, but revolver cartridges and the weapon itself are often carried close to the body so that they may not reach extremely low temperatures. The .22 Long Rifle cartridges of regular velocity show a velocity loss of from 8 to 10 percent, and the high velocity varieties of this cartridge about 3 to 5 percent. Modern shotgun shells show a loss of about 5 to 8 percent.

A low barometer will increase the remaining velocity and flatten the trajectory because the air is not so dense, and does not offer so much resistance. The greatest changes in barometer occur when going from sea level to high altitudes in mountain country. However, it cannot be said that high altitudes will invariably flatten the trajectory and cause the bul-

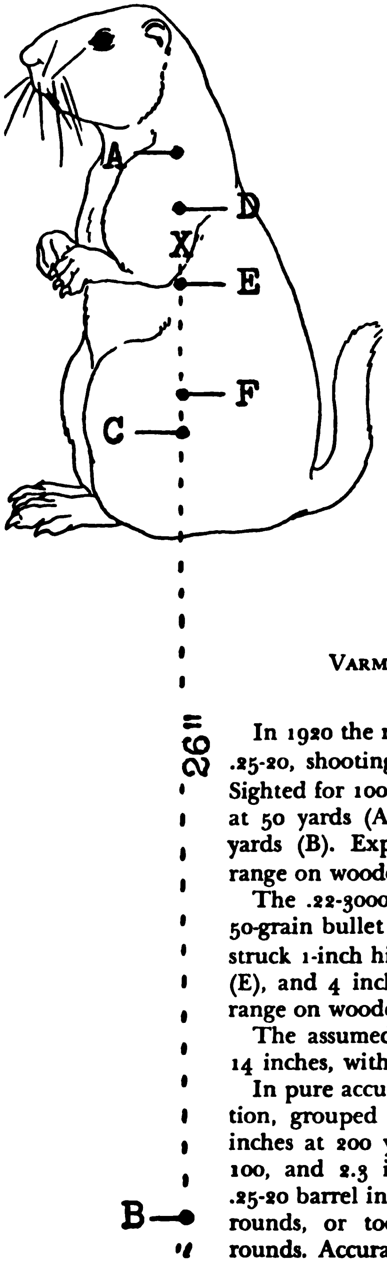


FIGURE 35 A

VARMINT CARTRIDGE IMPROVEMENT IN TWENTY YEARS

In 1920 the most popular varmint cartridge was the .25-20, shooting an 86-grain bullet at M.V. 1450 f.s. Sighted for 100 yards, the bullet struck 2.6 inches high at 50 yards (A), and dropped 26 inches low at 200 yards (B). Experience proved that its sure hitting range on woodchucks was about 125 yards (C).

The .22-3000 Lovell R-2 cartridge as of 1940, with 50-grain bullet at M.V. 3050 f.s. sighted for 175 yards, struck 1-inch high at 100 yards (D), 1 inch low at 200 (E), and 4 inches low (F) at 250 yards. Sure hitting range on woodchucks about 250 yards.

The assumed height of the woodchuck diagram is 14 inches, with point of aim at X.

In pure accuracy the .25-20, best rifles and ammunition, grouped in about 2.2 inches at 100, and 4.5 inches at 200 yards. The R-2 in about 1.1 inches at 100, and 2.3 inches at 200 yards. Accuracy life of .25-20 barrel in 1920 with chlorate primer about 1,000 rounds, or today with N.C. primer about 20,000 rounds. Accuracy life of R-2 about 7,000 rounds.

let to strike high, because high altitudes are usually accompanied by a lowering of the average temperature, and the two conditions would more or less balance each other. If, however, a high altitude were accompanied by a high temperature the effect might be quite noticeable, possibly to the extent of one to three minutes.

In a number of instances sportsmen have reported their rifles shooting higher at high altitudes. In every such report that the writer has seen the temperature was not mentioned. This casts doubt on the report. The change in sighting required may have been caused by the sportsman not assuming precisely the same firing position and tension of holding at the high altitude as he did at low altitude when he zeroed his rifle. Also the stock may have warped or shrunk between the two firings. Either of these conditions might cause a very considerable change in jump and consequently in location of center of impact. Therefore, in going to high altitudes it is very desirable to zero the rifle before hunting starts, to determine if there *has* been any change.

It is very apparent that such changes have more effect on rifles of medium velocity than those of high intensity. In the National Matches, prior to 1907, when the Krag-Jorgensen rifle (M.V. 2000 f.s.) was used, all expert riflemen found it very desirable to refer to both thermometer and barometer before setting their sights for long range. With the change to the Springfield rifle (M.V. 2700 f.s.) these two instruments disappeared from rifle ranges. With the latter rifle it has become the rule, when shooting in the summer months, to raise the elevation one minute above normal for extremely cold days (say plus 50° F) and to lower it one minute when temperatures approach 90 to 100 degrees.

With .22 caliber rim fire cartridges the dispersion is very noticeably increased at low temperatures. That is, the accuracy is not so good at temperatures below plus 60° F. However, this is probably due to the effect of the cold on lubrication and fouling rather than on velocity. The .22 Long Rifle cartridge gives its best accuracy on warm and humid days.

Trajectory Up and Down Slopes

So far we have considered the trajectory only on a level range; that is where the target is on a level with the gun, with a horizontal base line. What about shooting up or down hill with a slope range?

Ballistic calculations and experiments have shown that slopes of up to ten degrees up or down hill can be disregarded. There is no difference in the trajectory. Within this angle the trajectory is said to be "rigid."

Rifle shooters and hunters of fifty years ago have repeatedly stated

that a rifle shot high when shooting down hill, and that one should aim low or under the target or he would overshoot. Many recent writers have copied this statement. However, no one could explain just why. Many thought that the force of gravity augmented the velocity, but this could not have any appreciable effect on the result because even on a vertical shot straight down the acceleration would be only sixteen feet in the first second of flight, and even the slow moving .45-70 cartridge covers 400 yards in the first second of flight. Those were the days of open sights, and matters of jump and vibration were not well understood. It is thought that the old impressions arose because the problem of shooting up and down hill was more

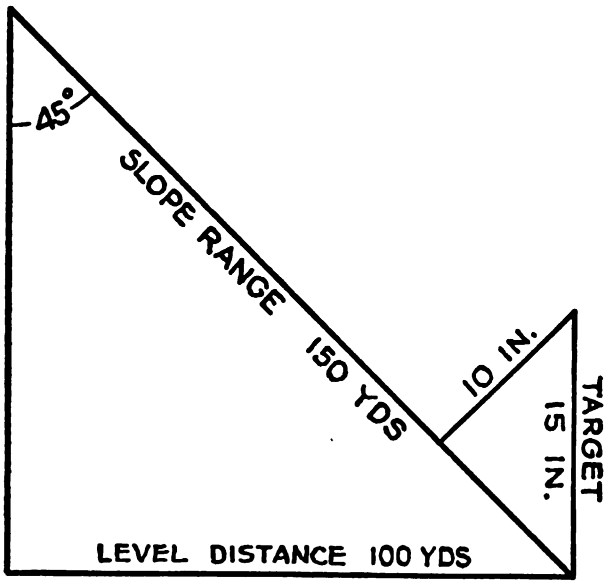


FIGURE 36. SHOOTING UP AND DOWN SLOPES

difficult because of the lessened height that the target presented, the less steady firing position, the tendency to overshoot with the open rear sights of those days, the difficulty of estimating distance on a slope, and particularly the effect on jump of shooting in an unaccustomed position with variations in the tension of holding. Misses often occurred, and they had to be accounted for somehow.

A distance which is 100 yards on a level will be 150 yards on a slope of 45 degrees. The latter is the distance from gun to target. The slope range is thus the base line for the trajectory, and is the distance for which the sights should be set. Theoretically the bullet, if fired down hill, will pass over the slope range in a little less time

than it would over a level range of the same length, for its velocity will be slightly augmented by the force of gravity, and vice-versa for firing up hill. But as we have seen these differences are so slight that they are inappreciable over practical rifle ranges.

In firing up or down hill the target, however, has less visible height because it is seen at an angle. Thus a target which is 15 inches high vertically, when viewed from above or below at an angle of 45 degrees, presents a height of only 10 inches. Therefore on a slope range we must take more pains in aiming because our target is smaller.

If, however, the range were straight up or down, that is a vertical range of say 100 yards, and we set our rear sight for the 100 yard horizontal adjustment, we would overshoot the target, that is hit away from our base line. Suppose the 100 yard angle of elevation for level shooting were 3 minutes. In shooting vertically there would be no drop of the bullet towards the base line from force of gravity. Therefore on a vertical range of 100 yards our bullet would strike 3 minutes or 3 inches away from the base line and point of aim.

Thus between a 10 degree slope and a vertical slope of 90 degrees there is a tendency to overshoot, being zero at 10° and then increasing proportionately up to 90° where it amounts to the change caused by the full angle of elevation at which the rear sight is set.

Over a slope of 400 yards, with the sights of the .30-06 rifle set for that distance, the sights would be at an angle of 11 minutes. Firing vertically at 90° the bullet would strike 44 inches away from the base line. On a slope of 50°, that is half way between 10° and the vertical, the rifle would overshoot half of this amount or 22 inches. Similarly, over a 200 yard slope range, with a 200 yard angle of elevation of 5 minutes, and on a slope of 50°, the rifle would overshoot 5 inches. But a 50° slope would be a very uncommon one in either hunting or warfare. On a 30° slope of 200 yards the .30-06 rifle would overshoot only 2½ inches.

But let us now revert to what the old timers found when shooting up or down a slope. A very common hunting cartridge in those days was the .45-70-500, black powder, M.V. 1315 f.s. The angles of elevation plus the jump were 18 minutes for 100 yards and 31 minutes for 200 yards. Therefore at 200 yards on a 50° slope, and with the sights set for that distance, the rifle would shoot 31 inches high, and on a 30° slope 15½ inches high. Apparently the old hunters were right when they stated that they had to hold low or aim under the target when shooting up or down steep hills.

Thus the allowance for steep slopes, either up or down hill, depends on the angle of elevation to which the sights are set, or roughly the velocity of the cartridge. With the .220 Swift cartridge, M.V. 4140 f.s., the 200 yard angle of elevation is only 1.5 minutes,

and no allowance whatever need be made for any slope range of as much as 200 yards.

When shooting up or down hill particular pains must always be taken with the aim, for the target will not present its full vertical height, and it is easy to shoot either under or over it. And we must also be most careful with our firing position, to take up the recoil on our shoulder in the same manner as we do when firing on a level, and to hold with the same tension, or the altered jump will put all our fine calculations at sea.

Revolver and Pistol Trajectories

Trajectory does not assume nearly the importance with a revolver or pistol that it does with a rifle, because the range is always short. Fifty yards may be considered the maximum pistol range because beyond that range pistol marksmanship and pistol trajectory present difficulties very hard to overcome. Primarily the revolver and pistol are weapons to be used in a hurry on a relatively large target (man target) at short range. In such use the trajectory over 50 yards or a shorter distance is so flat that no allowance need be made for the rise or drop of the bullet.

In competitive target shooting at 25 and 50 yards on the finely divided match targets now in use a small allowance is necessary, and in practice is made by adjusting the sights for the exact distance, or by aiming slightly high or low.

Most revolver and pistol cartridges have a muzzle velocity of from 800 to 900 f.s. With such, when sighted for 50 yards the bullet will strike about 1¼ inches above the point of aim at 25 yards. When sighted for 25 yards the bullet will strike about 2½ inches low at 50 yards. With the .357 Magnum cartridge, M.V. 1510 f.s., the corresponding figures will be about half the above. If one aims at 6 o'clock on the bullseye instead of at its center, allowance must also be made for half the diameter of the bullseye in order to strike in its center.

Extreme Range

"Range" is defined as a distance measured along the line of aim. The extreme range is the greatest distance to which the projectile will carry or fly when the line of aim is horizontal, and the barrel is elevated at a pre-determined angle. In other words, over a level plain, with the gun on a level with the plain, it is the greatest distance that the projectile can be made to fly before it strikes the plain or ground.

With all small arms the extreme range is obtained when the barrel is elevated at an angle of from 25 to 35 degrees. It is *not* obtained with an angle of elevation of 45 degrees as commonly supposed.

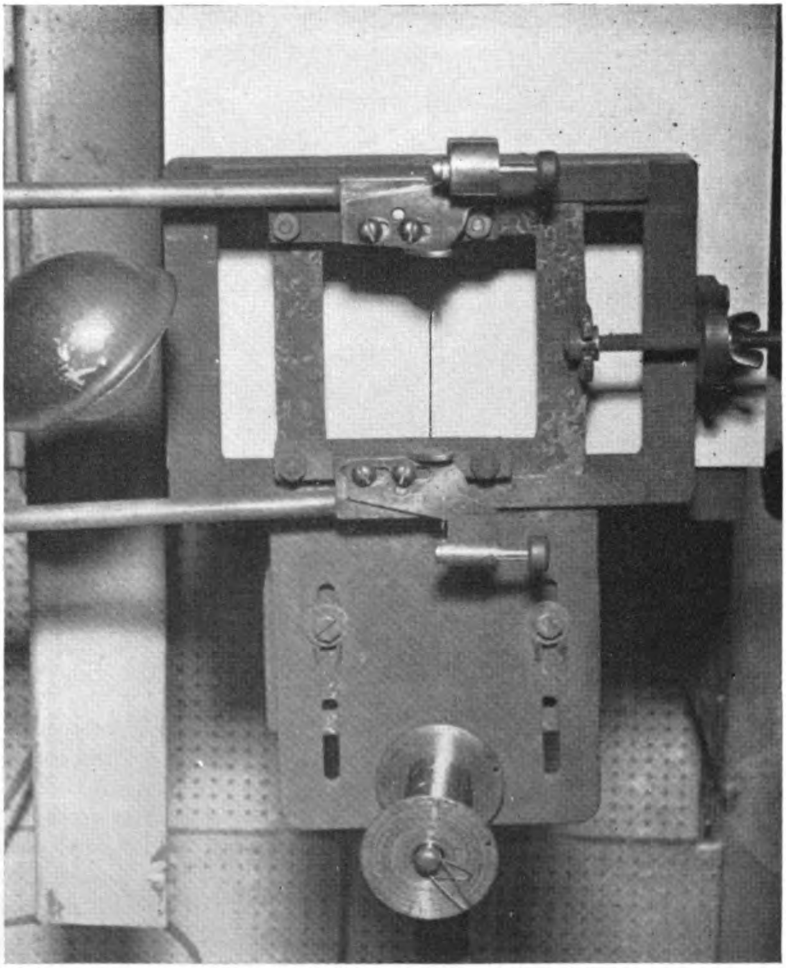


FIGURE 16

A muzzle wire type of disjunctor for breaking the current just in front of the muzzle when recording velocities. A sheet of white paper has been placed back of the carriage, and in front of the muzzle of the gun in an effort to show the extremely thin vertical wire running from the spool across the square opening. By means of the thumb screw on the right this wire can be moved from side to side to bisect the bore so it is cut by the bullet when the gun is fired. Courtesy of Remington Arms Co.

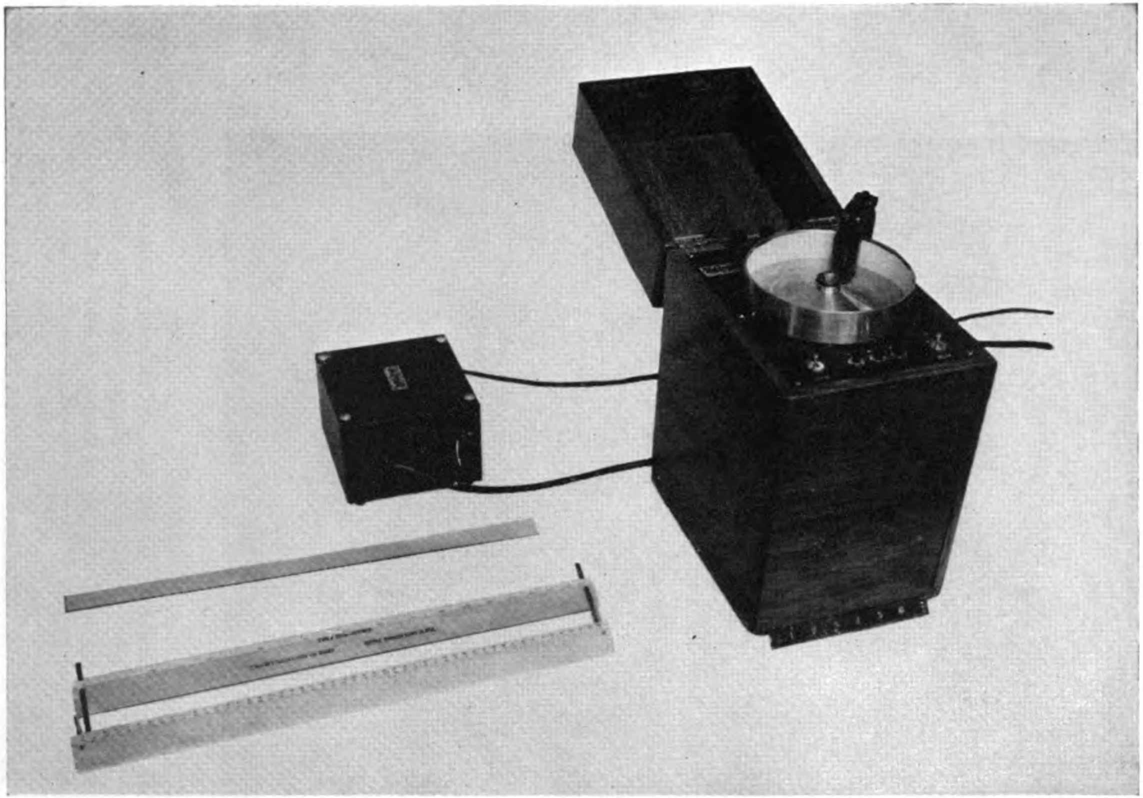


FIGURE 17

The Aberdeen Chronograph. The constant speed motor is within the box. The revolving drum contains the strip of paper held therein by centrifugal force, this strip being also shown at the left. The electric current thrown when the projectile passes through the muzzle screen, and again when it passes through the screen at the terminal target, jumps from the spark plug, through the paper strip, to the drum, making two minute holes through the paper. The distance between these two holes, measured with the scale shown, gives the time of flight between the two screens.

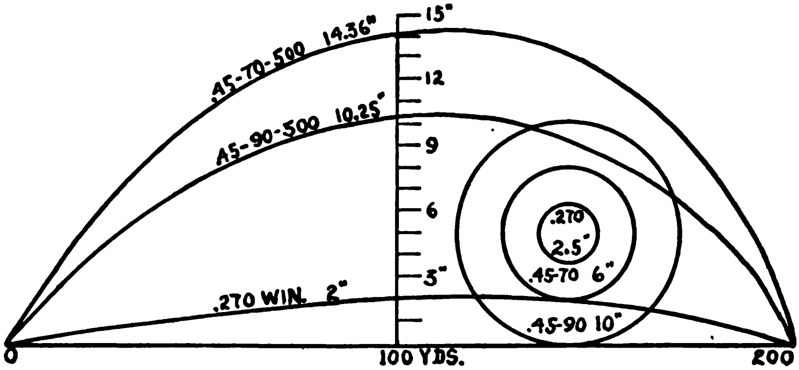


FIGURE 35 B

Thirty years' improvement in trajectory and accuracy of American hunting rifles. Trajectory curves show height at 100 yards when firing at 200 yards. Circles show average diameter of 10-shot groups at 200 yards under the best conditions.

The .45-70-500 and the .45-90-300 were the best black powder big game cartridges of 1895. The .45-90 represents about the flattest trajectory possible with black powder, obtained at a sacrifice in accuracy. The .270 Winchester with 130 grain bullet, a high intensity smokeless cartridge dating from 1925 has a sure hitting range on deer of about 325 yards, while that of the other two cartridges was about 150 yards.

With very long range cannon the extreme range is often obtained with an angle of elevation of over 45 degrees. With such an elevation the projectile will ascend to extremely high altitudes where the barometric pressure is very low, and the air is very rare. In such an atmosphere, where the resistance is small the projectile travels to a long distance before it starts to fall into denser air. This was the case with the German long range gun that shelled Paris in 1917. But no small arm projectile ever reaches such altitudes.

Extreme ranges are difficult to obtain by experimental firing, and when computed the results do not always prove correct. In the United States, for certain small arms, they have been determined experimentally by firing over the sea beach at Daytona, Florida, where the beach is washed clean at high tide so that the strike of the projectile can be found. Or by firing over a water target at Aberdeen Proving Ground, Md., or Fort Benning, Ga., where the splash of the bullet can be seen in the water, and located by observation through transits and triangulation. In these manners the following extreme ranges have been observed:

.22 Long Rifle, regular velocity, 40 grain round nose bullet, M.V. 1050 f.s.—1300 to 1400 yards.

.22 Long Rifle, high speed, 40 grain round nose bullet, M.V. 1350 f.s.—1400 to 1500 yards.

Ball Cartridge, Caliber .30, Model 1906, 150 grain pointed bullet, M.V. 2700 f.s.—3300 yards.

Ball Cartridge, Caliber .30, M1., 173 grain pointed, boat tailed bullet, M.V. 2640 f.s.—5700 yards.

Ball Cartridge, Caliber .45, M 1911—.45 Colt Auto Pistol—230 grain round nose bullet, M.V. 825 f.s.—1600 yards.

The following extreme ranges have been computed. Probably some errors exist.

Ball Cartridge, Caliber .30, M 1898 (.30-40 Krag.)—4066 yards.

.303 British Mark VII Cartridge, 174 grain pointed bullet, M.V. 2440 f.s. Elevation 34° 42′—4457 yards (British "Text Book of Small Arms, 1929").

.45-70-500 U.S. Govt. 500 grain round nose bullet, M.V. 1315.7 f.s. Elevation 29° 45′ 36″.—3500 yards. Time of flight 21.2 seconds, penetration 10 inches in sand. (It is not known if this was computed or determined experimentally.)

The reason why the Caliber .30 M1 cartridge ranges so much further than the others is because the boat tailed bullet overcomes the resistance of the air much better than a flat base bullet, particularly when the remaining velocities are below the velocity of sound.

It will be noted that the pasteboard cartons in which .22 Long Rifle cartridges are packed contain the caution; "Dangerous at One Mile." These little bullets, and all other rifle and pistol bullets, retain sufficient energy even at their extreme range, to cause a penetration that would be dangerous to human beings.

CHAPTER VI

Determination of Trajectory

THE trajectories of all common military and sporting cartridges have been accurately determined and are given in the appendix. Trajectory figures for sporting cartridges are usually given only to 300 yards, but for greater distances they can be easily computed from the Tables of Angles of Elevation. Thus it is only where we are using a new or strange cartridge or load that we have the problem of determining the trajectory.

If we are using a known cartridge with a known bullet, but with a hand load that gives a different velocity from the standard load, we can usually interpolate between standard load figures to obtain the approximate trajectory. It does not pay to quibble over such small differences as half an inch in trajectory figures, for such differences occur between two manufactured lots of the same carrtidge, or two lots of the same powder, or bullets, or cases, and two different barrels may give slightly different results. Particularly the algebraic sum of all these may well exceed half an inch even at 100 yards.

If we know the muzzle velocity of our strange cartridge or load, then we can determine the Ballistic Coefficient C, the trajectory, remaining velocity, angle of departure, time of flight, angle of fall, wind deflection, and energy from the du Pont Exterior Ballistic Charts described further in this chapter, and contained in the rear of this work. Certain "rules of thumb" are also given by which some of this data can be computed. Such computations will give fairly accurate results, but only the screen test to be described hereafter is without error when properly conducted.

But if we do not know the muzzle velocity of our strange cartridge, then we must determine its trajectory by a firing test, or a series of such tests. Firing tests to determine trajectory are of two kinds:

1. We can determine trajectory, subject perhaps to some slight errors, by firing at the distance at which we desire to determine the rise or fall of the bullet, with sights accurately adjusted for the basic distance. For example, if the basic distance over which we wish to

determine the trajectory is 200 yards, and we wish to know the height of trajectory at 100 yards when firing at 200, we can set the rear sight accurately for 200 yards, and then fire on a target set at 100 yards, and measure the height that the bullet strikes above the point of aim on that target. Or similarly on a 300 yard target we can find the drop of the bullet at that distance when sights are set for 200 yards. If the experimenter is a good rifle shot, uses care, follows the procedure described below, fires a series of shots and takes the average, there should be no error of any consequence.

2. We can determine the trajectory by a screen test, firing on a terminal target through screens placed at intermediate distances. The height of the bullet hole in the screens above a base line connecting the center of the bore at the muzzle with the center of the bullet hole in the terminal target, will give the trajectory accurately. This method entails considerable labor in laying out the base line accurately and erecting the several screens.

To Determine Trajectory by Firing at a Given Distance with Sights set for the Basic Distance

A certain procedure is necessary in order to avoid prohibitive errors that might result from variations in jump, vibration, light, and wind.

Suppose we desire to determine the height of trajectory at 100 yards, and the fall of the bullet at 300 yards, above and below the line of aim, when our sights are set correctly for 200 yards.

On our rifle range we set up targets with bullseyes or other aiming points, at 100, 200, and 300 yards, so that the three targets are almost in line, one with the other, but unmasking each other just slightly so that all three bullseyes can be seen from the firing point and so that an absolutely minimum change in our firing position will enable us to fire on any one of them, as shown in Figure 37.

Assuming a steady firing position, we first fire on the 200 yard target and adjust our sights until our bullets average striking the point of aim. Then without getting out of position, and with the minimum change in our position, sight adjustment remaining the same, we shift our aim very slightly to our left and fire, say three shots, on the 100 yard target. Then shift back on the 200 yard target to see that we are still grouping on the point of aim on that target. Then we shift our aim very slightly to the right onto the 300 yard target, with no change in position and without taking the rifle from the shoulder, and fire three shots on that target—with our 200 yard sight setting, of course. Disregard any shots that were not pulled with a perfect aim and trigger squeeze. Be extremely careful that no change in the firing position, tension of holding, etc., occurs from

shot to shot or target to target. Keep the butt of the rifle at the shoulder, and upper arms and elbows in the same position throughout the entire test. If any slip should occur, disregard the whole test and start over.

On the 100 yard target measure the vertical distance from the point of aim to the center of each bullet hole, and take the average

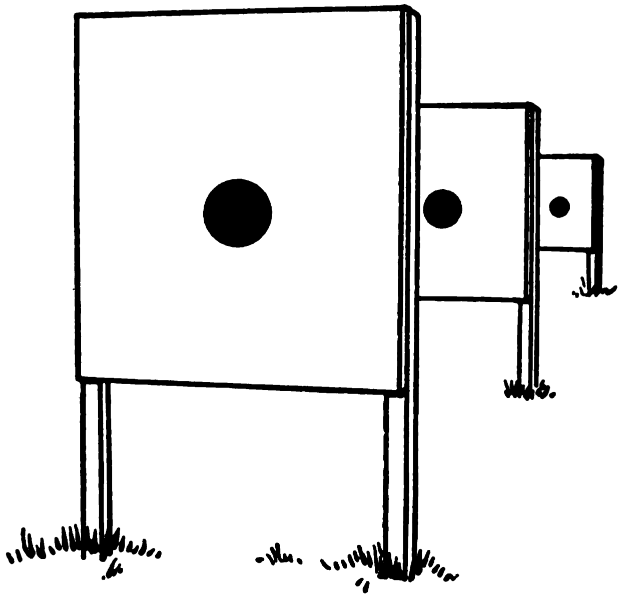


FIGURE 37. TARGETS BARELY UNMASKING EACH OTHER FOR TRAJECTORY TEST. AS VIEWED FROM FIRING POINT.

as the height of trajectory above the line of aim at 100 yards when sights are set for 200 yards.

On the 300 yard target measure the vertical distance, downward, from the point of aim to the center of each bullet hole, and take the average as the drop of the bullet at 300 yards when firing with sights set for 200 yards.

If using conventional black bullseyes for aiming points, and if aiming at 6 o'clock on each bullseye, the bottom edge of the bullseye, and not its center, is of course the point of aim. Bullseyes can be any size desired at the various distances to give clear aim.

Such a test involves firing a rather long series of shots, and a very steady and comfortable firing position is highly desirable as the tester must stay in position without any change from the first to the last shot. The writer very much prefers to fire from a bench rest

because it is steadier and less fatiguing, and after becoming used to one's own bench there is less variation in position and tension from shot to shot than in any other position.

Such a test could be made by firing prone from a sandbag rest, or even prone with the gunsling, but there would probably be a greater number of poorly aimed and squeezed shots to be disregarded, and the test might be so prolonged that one would become tired towards its end, marksmanship might become uncertain, and the entire test might have to be done over at some other day.

In order to be able to identify bullet holes, and to disregard poorly aimed and squeezed shots, a spotting scope capable of resolving the bullet holes at 200 yard is very desirable. Also, such a test is more easily and accurately conducted with a rifle equipped with a telescope sight, and with targets having a prepared aiming point such as a black bullseye with a white center in which the cross hairs of the telescope sight can be accurately centered. But the test can also be conducted with iron sights provided no decided change in light occurs during the test.

No reliable results can be obtained (unless the test is often repeated and an average taken) by first firing at 200 yards until sights are correct, then getting out of position, perhaps moving the target to 100 yards, getting into position again and firing on that target, and doing the same for 300 yards. In each position there will almost certainly be differences in jump and vibration that will negative the results. See Chapter IV.

The writer has frequently completed a test of this kind on three targets within an hour of firing, and where a known cartridge was used the results have checked almost precisely with the official trajectory tables, taking into consideration the difference between trajectories measured from the line of aim and those from the base line. There is something very satisfying to the rifleman in a test of this kind. He sees exactly how his own rifle and ammunition, in his own hands and aimed with his own eyes performs as to accuracy and trajectory. And when he has repeated it several times and has obtained the same results he begins to place the greatest reliance on his rifle. He gets to know it like unto his alphabet. This is particularly true if he conducts the test each summer before he takes his rifle into the hunting field. It is also just the kind of a test every Infantry soldier should be given opportunity to conduct just before he enters the theatre of operations, and whenever he is issued a new rifle.

Of course the test can be conducted at any distances in order to determine the exact data desired. Thus we might have targets at 100, 200, 300, 400, and 500 yards to determine complete trajectory over 500 yards. But such an extended test would involve firing many

shots, and occupy much time, and should be attempted only by a rifleman in hard training, as otherwise he might become tired and unsteady before its completion.

Screen Tests

A fairly level range is necessary, and the firing must be done either from a bench rest or a machine rest. A machine rest is usually available only at a regularly established ballistic station. The writer has used a bench rest for all his private screen tests. To establish the base line either a 10 or 20 power telescope sight, dismounted from the rifle, was used. A wooden "V" block was arranged to hold the sight with its center at the same height above the bench top that the center of the bore of the rifle assumed when it was fired. A tack

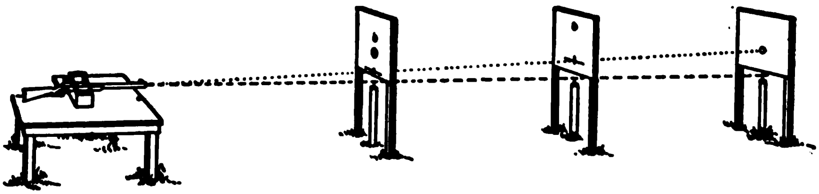


FIGURE 38. DIAGRAM OF BENCH REST, TWO SCREENS AND TERMINAL TARGET ARRANGED FOR SCREEN TEST. DASHED LINE IS PERMANENT BASE LINE. DOTTED LINE IS BASE LINE FOR TRAJECTORY.

driven in the top of the bench served as a point from which to verify the height of both scope and bore.

Stout posts should be sunk in the ground at each screen and target position, and their tops approximately alined with the telescope. An assistant then drives a nail in the top of each post, driving it down until all nail heads are in line as viewed through the telescope in position on the bench rest. This procedure is tedious, but once done it never has to be repeated, except that each spring the alinement should be verified to see that it has not been disturbed by frost or weather. The center of the telescope on the bench rest, and the tops of the nails establish the permanent base line. See Figure 38.

Above each post and nail head a target frame is erected to carry the screens and terminal target. These frames and the screens and targets placed on them must be of sufficient height and size to contain the trajectory of any cartridge that is likely to be fired on them, and they must be directly in line with one another so that a bullet which strikes the terminal target will pass through every screen.

For the intermediate screens the best paper is a thin bond paper similar to best quality writing paper. Such a paper as will be punctured by the point of the bullet, but between the point hole and the

circumference of the entire bullet hole the paper will be pushed back and blackened. The bullet hole remains much smaller than the bullet diameter. Then if the point hole is not in the center of the entire hole it shows that the bullet was tipping and that yaw was present. If the bullet tips, thus showing yaw, the results will not be reliable, as at that screen the bullet may strike higher or lower than it normally should. However, it is comparatively seldom that we encounter yaw.

The terminal target is first placed in position and the telescope in position on the bench rest is directed and alined on it at a point half way between its center and its bottom edge. Then keeping the telescope in position, the nearest screen (say 100 yards) is placed in position, and an assistant pastes a bullseye or aiming point on it, alined with the telecope. Then when a shot is aimed at this point on the nearest screen, the rifle having its sights adjusted for the terminal range, the bullet will pass through all the screens and strike the terminal target a little distance above its bottom. The intermediate screens are then placed in position.

The rifle, loaded and with its sights set correctly for striking the terminal target, is then substituted for the telescope on the bench rest, and is aimed at the aiming point on the nearest screen. An assistant verifies the height of the center of its bore at the muzzle above the tack on the bench to see that it is the same height as the telescope was. If necessary, the rifle is shimmed up or down by varying the amount of padding on the forearm rest. When everything is correct a shot is fired.

Then go to the terminal target and measure the height of the center of the bullet hole above the nail head representing the permanent base line. On each of the screens measure up vertically from the nail head on the permanent base line an amount equal to that which this measurement on the terminal target bears in proportion to the distance, and draw a cross on the screen. That is, if the vertical distance from the permanent base line to bullet hole in the terminal target is 20 inches, and the terminal target is at 500 yards, then the cross on the 400 yard screen would be placed 16 inches above the permanent base line, and 12 inches on the 300 yard screen, 8 inches on the 200 yard screen, and 4 inches on the 100 yard screen. These crosses on the screens then indicate the new base line for the measurement of the height of trajectory of that particular shot that has just been fired. Measure vertically from the cross to a horizontal line drawn through the center of the bullet hole in the screen, and that measurement is the height of trajectory at the distance at which that screen was placed.

We then have a complete record of the flight of the bullet, and the trajectory from muzzle to terminal target, recorded at each dis-

tance at which a screen has been placed. If the layout and work has been correct there is no error. We may verify it by firing several more shots, for each of which we will of course have to establish the base line for that shot from the permanent base line as described. If the velocity is uniform, there is no yaw or tipping of the bullet on any of the screens, and no retarding or accelerating wind, these measurements for a series of shots should be identical within a small fraction of an inch.

The initial preparation of the range, laying out of the permanent base line, erection of frames, etc., may take a week, then all is prepared for a whole season of test work. Afterwards a shot can be fired and measurements made in perhaps an hour per shot. Precision work and close concentration throughout is required.

Numerical Determination

There are certain intricate formula and tables by means of which the ballistican can compute the trajectory, time of flight, etc., when the form, shape, dimensions, and weight of the bullet can be examined, and when the muzzle velocity is known. But such computations require a knowledge of higher mathematics, and do not come within the scope of this work.

But there are also certain charts or graphs, and certain simple "rules of thumb" by means of which the average man can solve many of the problems arising in exterior ballistics. For some solutions the muzzle velocity must be known, and this must be established as described in Chapter III. Reference is now made to the du Pont Exterior Ballistics Charts found in the pocket at the rear of this work.

The Ballistic Coefficient

In many calculations it is necessary to determine the Ballistic coefficient "C" which is the index of the ability of the bullet to overcome air resistance. C is determined by dividing the sectional density by the form factor "i." Or in simple language the ability of the bullet to overcome air resistance depends on its weight in proportion to its diameter, and the shape of its point.

Take two bullets each weighing 180 grains—the 180 grain .30-06 sharp pointed bullet, and the 180 grain .38-40 flat point bullet. Both have the same weight, but the former is much smaller in diameter than the latter. But, on account of its diameter and the shape of its point, the .38 caliber bullet has to push along much more air than the .30 caliber bullet, yet both have the same weight to do the pushing with. The .30 caliber bullet has much the greater sectional density.

Sectional Density

To determine sectional density, divide the weight of the bullet (in pounds) by the square of its diameter in inches. Thus the formula would be $\frac{W}{d^2}$. To convert 180 grains to pounds divide by 7,000, and use the actual, not the nominal diameter of the bullet. Thus $180 \div 7000 = .257$ pounds. $.308 \times .308 = .94864''$. Then, $.257 \div .94864 = .270$ the sectional density of the 180 grain .30 caliber bullet.

Coefficient of Form

Next we must have the form factor "i," or as it is sometimes called, the Coefficient of Form. This is an index of the shape of the point. The sharper the point of the bullet, including its ogive or slope of point from point to maximum diameter, the more effectively will it push through the air. We determine this coefficient of form from Chart 1 of the du Pont Ballistic Charts, and find that in the case of the above .30 caliber 180 grain bullet with sharp point (which bullet incidentally has its ogive drawn on a radius of 9 diameters) that "i" is .465, the desired coefficient of form.

Now we are getting somewhere. The Ballistic Coefficient C, as we have seen, is the sectional density divided by the coefficient of form, or expressed as a formula $C = \frac{W}{id^2}$. In the present example $.270 \div .465 = .580$. That is the ballistic coefficient of our 180 grain .30 caliber pointed bullet is .580.

Or instead of going through all these calculations in arithmetic we may obtain the ballistic coefficient directly from Charts 1 and 2 of the du Pont series.

Remaining Velocity, Angle of Departure, Time of Flight, and **Maximum Height of Trajectory,** can all be determined from the du Pont Charts 3 to 6 respectively. For all these, of course, we must know the muzzle velocity. We cannot get along without the muzzle velocity, which is measured as described in Chapter III.

Drop of the Bullet. By rule of thumb calculation the drop of the bullet at any range can be easily determined. The drop of the bullet in feet equals 16 times the time of flight squared. The drop in inches will of course be twelve times what it is in feet. The time of flight, if not known, can be obtained from du Pont Chart No. 5. We can also determine the drop of the bullet from the Table of Angles of Elevation in the Appendix, or from a graph of the trajectory, in both cases as described in the preceding chapter. If the angles of elevation are not known, they can be determined with the aid of du Pont Chart No. 4.

Time of Flight. If we know the height of trajectory for any range we can determine the time of flight for that range. The height of trajectory for all common cartridges is given in the tables in the Appendix, or for a strange cartridge it can be determined from du Pont Chart No. 6. The height of trajectory *in feet* at its highest point equals four times the square of the time of flight. Or without going into this calculation we can determine the time of flight directly from du Pont Chart No. 5.

Angle of Fall and **Wind Deflection** can be determined from du Pont Charts Nos. 7 and 8 respectively.

Energy. The energy of the bullet at the muzzle, or at any range can be determined from du Pont Chart No. 9, or it is about as easy to calculate it. The energy of the bullet in foot pounds is equal to the weight of the bullet (in pounds) multiplied by the velocity squared, and divided by the acceleration of gravity, or 32.16.

To simplify this; square the velocity, multiply by the weight of the bullet in grains, and divide the result by 450240. For muzzle energy use the muzzle velocity, and for energy at any other range use the remaining velocity at that range.

CHAPTER VII

Wind Deflection

WIND is the greatest disturbing factor to the flight of the bullet that the rifleman has to contend with. It is also a factor that no rule, method of computing, or observing, will result in arriving at a correct solution. Calculation of wind drift has, so far, never been much more than an approximation.

The effect of a side wind blowing on a flying projectile is to cause it to drift slightly with the wind out of its normal straight course. A head wind retards the bullet, and a rear wind accelerates it, causing it to strike lower or higher than normal. Whether the wind deflects the bullet by pressing on it, or because the bullet is floating in a moving medium, we do not know; but the result is the same.

It is important to know the direction and velocity of the wind. Consider the rifle range as though it were the face of a clock, laid on its back, the target being at 12 o'clock, and the shooter at 6 o'clock. Then a wind blowing from the right at exactly right angles to the line of fire would be a 3 o'clock wind, and one blowing straight towards the shooter would be a 12 o'clock wind. Three and nine o'clock winds cause the greatest lateral deflection. It has been assumed that 2, 4, 8, and 10 o'clock winds cause about seven-eighths the side deflection of 3 and 9 o'clock winds, and that 1, 5, 7, and 11 o'clock winds have about one-half the effect.

The velocity of the wind is always stated in miles per hour of its drift. The velocity can be measured with an instrument termed an anemometer. In the absence of such an instrument it must be estimated. The following description will assist in such an estimate:

1 mile per hour	Hardly appreciable.
2 to 4 " " "	A very light breeze.
6 to 8 " " "	A gentle, pleasant breeze.
10 to 12 " " "	A rather strong breeze.
14 to 18 " " "	Quite a strong wind.
20 to 25 " " "	A very hard, strong wind. We pull our hats on tighter and lean against it.
Over 30 " " "	A strong gale, too strong for any successful rifle shooting.

On some rifle ranges it has been customary to place wind flags along the edge of the range so that the wind velocity could be judged by the angle at which the flag was blown away from its staff. Of course, such an indication is of no value unless it has been studied in connection with an anemometer, as flags of different size and materials will stand out differently, and also the weight of the material will vary according to the humidity of the air.

The impossibility of a really accurate determination of wind deflection is seen when we examine a wind vane and an anemometer in use in any wind of material velocity. Even with a wind which we would consider by its feel to be quite steady, the direction will be seen to change an hour or two almost constantly. And the velocity is also constantly changing as much as two to five miles per hour. These changes sometimes occur from second to second, and seldom does the wind remain constant for more than five seconds at a time. Therefore it is impossible to make any exact allowance. All we can do is to allow for the average direction and velocity and trust to luck. If our luck is not good, and our bullet strikes far to one side or the other we explain it by saying that the bullet was "blown out by a puff of wind."

Slight changes in wind velocity, and changes in direction when the wind is around 6 or 12 o'clock, may be seen by watching the drift of mirage which is almost always present in summer. A spotting scope, or any telescope of ten power or higher, is laid and focused on the target. The atmosphere will then appear to move or "boil" like water boiling in a saucepan, or water flowing over the bed of a clear brook. The direction of mirage flow indicates the direction of the wind, and changes in velocity of flow indicate changes in wind velocity. If the mirage "boils" straight up it indicates a 6 or 12 o'clock wind or else a lull in the breeze. There is, however no indication by which we can tell miles per hour of velocity, but only slight changes in velocity. The telescope is usually set up on its stand to one side of the shooter. The difficulty then arises in getting one's eye from the telescope to the rifle sights, and getting the shot off before the mirage and wind change. Better results can be obtained when a high power telescope sight is mounted on the rifle, in which case the mirage can be watched while one is aiming, and the shot can be got off with no delay other than that to insure a good trigger squeeze. Mirage is thus a considerable aid to securing high scores, but its discussion belongs properly in a work dealing with rifle marksmanship.

Wind direction being the same, the deflection of any particular bullet is approximately in proportion to the velocity of the wind. At the same range a 10 mile wind will deflect a given bullet, fired at a given velocity, twice as much as will a 5 mile wind. But various

bullets at various velocities are not equally affected by the same wind. Nor can it be stated positively that a bullet flying at a high velocity will be deflected less than will the same bullet at low velocity. Neither will a heavy bullet be surely deflected less than a light one. The longer the range the greater will be the wind drift, but not in proportion to the length of range.

The ballistician states that the side deflection of the bullet is in proportion to:

1. The velocity and direction of the cross-wind.
2. The length of the range.
3. The delay of the bullet over the range.

The "delay" is the difference in time of flight over a given range, between the actual observed or measured time, and the time calculated from the muzzle velocity had the bullet been fired in a vacuum. The delay is thus dependent upon the ballistic coefficient of the bullet and its muzzle velocity. Bullets starting at a low velocity will sometimes fall off less in velocity in proportion to their muzzle velocity, have less delay, and require less wind allowance, than the same bullet starting at a higher velocity. This is because a bullet starting at a high velocity encounters a very much higher air resistance than the same bullet starting at a lower velocity.

This is why, for example, the bullet fired from the .22 Long Rifle cartridge, regular velocity, M.V. 1050 f.s., is deflected much less by wind than is the exactly similar bullet fired from the .22 Long Rifle high velocity cartridge, M.V. 1375 f.s. It also explains why sharp pointed bullets of the same caliber, weight, and velocity require less wind allowance than round or flat point bullets.

Retardation and acceleration of flight due to head and rear winds, and the consequent lower or higher point of impact, are very slight at wind velocities under 25 miles per hour. The effect is sometimes seen when target shooting at 1,000 yards, not surely by any one individual, however, for his observed differences in elevation might be due to jump and vibration caused by his firing position. But it may show in the average change in elevation required by the members of a rifle team.

For the more common cartridges used by target shooters, specifically the .22 Long Rifle Regular, the .30-40-220 Krag, and the Ball Cartridges, Caliber .30, M 1906 and M2, complete windage tables have been worked out, and are published in works on rifle marksmanship. No claim is made that these tables are correct. In fact they are probably more or less full of small errors. But over many years of use they have proved to be fairly good and reliable guides for target shooters. Wind gauges set with reference to them usually result in the shot striking very close to the bullseye.

The .30-40-220 Krag table was prepared by the late Dr. W. G.

Hudson. The .22 Long Rifle and .30-06 tables were prepared by the writer. He holds no brief for them other than that they have been useful. All these tables were prepared on the same basis and with the same assumptions. From rough experimental firing it was determined that at 500 yards a 3 or 9 o'clock wind of ten miles per hour deflected the 220 grain Krag bullet approximately 50 inches, and the 150 grain .30-06 pointed bullet approximately 25 inches. At 100 yards a similar wind deflected the .22 Long Rifle bullet about 3.6 inches, and at 200 yards about 14.4 inches. Winds from 2, 4, 8, and 10 o'clock were assumed to give seven eighths of this deflection, and those from 1, 5, 7, and 11 o'clock one half the deflection of 3 and 9 o'clock winds. It was further assumed, probably not exactly correctly, that the deflection at 200 yards would be one fourth that at 500 yards, and at 1,000 yards about four times that at 500 yards.

Of equal usefulness, and probably also containing small errors, is the rough rule for computing wind allowance with the Ball Cartridges, Caliber .30, M 1906 and M2, as given in the Army Training Regulations on Rifle Marksmanship.

"The range in hundreds of yards (expressed as a single figure) times the velocity of the wind in miles per hour, divided by ten is the number of quarter points (Minutes) of wind gauge correction to allow for a 3 or 9 o'clock wind. Winds one hour from 3 or 9 o'clock (2, 4, 8, and 10 o'clock) require about the same windage; 1, 5, 7, and 11 o'clock winds require half as much allowance as those from 3 or 9 o'clock."

Examples: A 3 o'clock 10 mile wind at 500 yards—5 × 10 ÷ 10 = 5 quarter points, or 5 minutes, or 25 inches, which is the same as in the writer's table above. The same wind at 1,000 yards—10 × 10

Cartridge	*Bullet. Grains & Kind*	*Velocity f.s.*		*Loss in 300 yds. %*	*Wind Drift. 15 MPH at 300 yds.*
		Muzzle	*300 yds.*		
.220 Swift	48 SP	4140	2265	45	.99 ft.
.22 Savage HP	70 SP	2780	1930	30	1.05
.250 Savage	87 SP	3000	2190	27	.92
.280 Ross	145 PP	3050	2440	19	.55
.30-30 WCF	170 SP	2200	1470	33	1.58
.30-06 Govt	165 AP *	2700	2130	21	.73
.30 Newton	150 SP	3200	2475	22	.63
.300 Magnum	180 HPBT	3060	2200	28	.93
.45-70	405 SP	1310	985	25	2.00

* Armor Piercing, pointed, flat base.

÷ 10 = 10 quarter points or 10 minutes or 100 inches, while the writer's table gives it as 110 inches.

In the May 1943 issue of The American Rifleman, Mr. E. Baden Powell gives the wind-drifts at 300 yards in a 15 mile wind at right angles. The writer quotes the abbreviated table on preceding page.

The wind deflection of bullets at various speeds is complicated and not well understood. Apparently there are certain "zones of velocity" for various bullets within which the deflection may be considerably more or less than in other zones, and a zone of higher velocity may actually result in more deflection than a lower one. Doubling the muzzle velocity of the bullet does not necessarily double its remaining velocity at any distance beyond the muzzle.

Mr. Wallace H. Coxe has calculated the following wind deflections in terms of minutes and seconds for cross winds of ten miles per hour over a range of 300 feet:

Cartridge	*Bullet, grains*	*M.V. f.s.*	*R.V. f.s. 300 feet*	*Wind Deflection*
.22 Long R.	40 Lead	1,070	932	3.29′
.25-20 W.C.F.	60 H.S.	2,200	1,706	3.18′
.25-35	117 S.P.	1,975	1,664	2.32′
.250-3,000 S.	87 Ptd.	3,000	2,639	1.10′
.250-3,000 S.	100 S.P.	2,850	2,589	.52″
.270 Win.	130 Ptd.	3,160	2,958	.32″
.30-06 U.S.	110 H.S.	3,500	3,059	1.00′
.30-06 U.S.	150 Ptd.	2,700	2,416	1.05′
.30-06 U.S.	180 Ptd.	2,700	2,533	.35″
.30-06 U.S.	180 Exp.	2,700	2,463	.52″
.30-30 Win.	170 S.P.	2,000	1,722	1.97′
.30-40 K.	220 R.N.	2,000	1,787	1.46′
.32-20	80 H.S.	2,000	1,560	3.41′
.32 Special	110 H.S.	2,550	2,157	1.68′
.32-40	165 S.P.	1,500	1,248	3.27′
.35 Rem.	200 S.P.	2,000	1,753	1.74′
.38-55	255 M.C.	1,700	1,403	3.08′
.40-65 Win.	260 Lead	1,420	1,163	3.93′
.40-70 Win.	330 Lead	1,380	1,192	2.92′
.40-90 Sharp	370 Lead	1,400	1,212	2.78′
.45-70 U.S.	405 Lead	1,360	1,158	3.37′
.45-70 H.S.	300 S.P.	1,890	1,461	3.79′
.45-90 Win.	300 Lead	1,550	1,225	4.35′

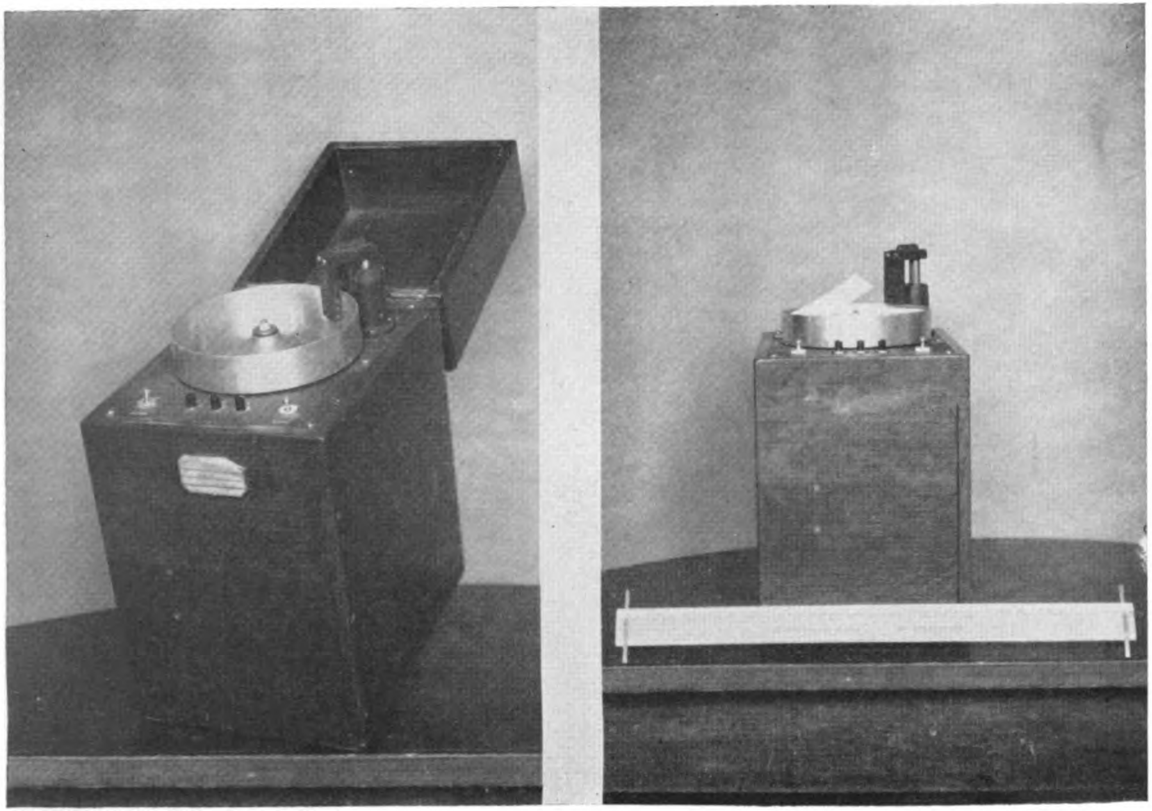


FIGURE 18

Other views of the Aberdeen Chronograph. The left one shows the sharp point of the spark plug, and the right one the strip of paper just being inserted within the drum. The chronograph is easily portable, and can be used wherever electric current is available.

FIGURE 19

The Remington Arms Company Pressure Indicator operates in conjunction with the quartz crystal pressure gauge on the gun. The circuit is so designed that the peak of the complete pressure-time curve registered by the quartz crystal is read directly by the instrument in pounds per square inch. This instrument can be used with any of the ordinary pressure gauges and guns suitable for the measurement of pressures with copper or lead crusher cylinders. The unit containing the quartz crystal is simply substituted for the copper or lead crusher cylinder.

Wind Deflection

It is believed that there is no branch of exterior ballistics in which there is more need for future investigation than wind deflection. Such investigation has been delayed, perhaps, because it is both tedious and costly, particularly in labor. And it requires a long range open to winds, which is not available everywhere. There are many modern cartridges which we know will require very different wind allowances from the three cited above, but as yet we cannot give to the rifleman even an approximation of what the allowance should be for these. Approximate tables would be of great help to riflemen, just as those for the .22 Long Rifle, .30-40, and .30-06 have been of help.

CHAPTER VIII

Wounding Effect and Killing Power

THEORETICALLY, the wounding effect and killing power of any bullet would depend on its striking energy in foot-pounds. But here theory and practice decidedly part company, for other factors have been found to be so important in governing wound effects that today energy is scarcely ever spoken of in this connection.

Within our lifetime we have seen rifle bullets vary in weight from 900 to 35 grains, and in diameter from .600 to .220 inch, and velocities have progressed from 1,000 to 4,300 feet per second. We therefore think it desirable to review a little of the past history of wounding effect.

From the introduction of the breech loader up until about 1892 the typical military rifle bullet was one of about .43 to .45 caliber, weighing about 430 to 500 grains, and of lead slightly alloyed with tin. The muzzle velocity was about 1300 f.s. Up to at least 600 yards such bullets almost invariably drove completely through the bodies of human beings, and there was usually a decided "knock down" blow. When they struck in a vital part such bullets killed instantly. They usually drilled a more or less clean hole through flesh and bone, and there was little laceration of tissue beyond the bullet hole. On horses they were also very effective. The bullet usually expanded a little during its penetration, but the exit hole, as a rule, was not much larger than the entrance hole.

Sportsmen also used bullets of about these calibers, and weighing from 300 to 550 grains, and with velocities from 1300 to 1500 f.s., for big game the world over. We in the United States have memory of the extensive use of smaller and lighter bullets, .32 to 40 caliber, and weighing from 165 to 330 grains, but the use of such projectiles was confined almost exclusively to the white-tailed deer of America. The typical big game rifle of the period from 1870 to 1898 was of .45 caliber, shooting a bullet of from 350 to 550 grains and with a charge of black powder sufficient to give it a muzzle velocity of from 1300 to 1500 f.s. The trajectory of the cartridge was such that hits could not be assured much beyond 150 yards, but up to that distance such projectiles were most satisfactory in their killing power on all

soft-skinned large game. They delivered a knock down blow, and when the bullet struck in a truly vital part of the animal, or in the chest cavity, it killed instantly or within a few minutes. But hits in the abdominal cavity were not so certain. The thought at that time was that the ideal bullet should just shoot through the animal to its opposite side, and lodge under the skin without penetrating clear through, thus expending all its energy on the beast. In those black powder days it was quite clear that killing power depended on the following factors in the order of their importance:

1. Weight.
2. Sectional Density.
3. Diameter.
4. Shape of Point.
5. Hardness of Bullet.

A .45 caliber bullet of 400 to 500 grains had all of the first three qualities to a superlative degree. A flat pointed bullet was slightly superior to one with a round nose, and both very much better than a sharp point. Bullets cast of pure lead killed better than those hardened with tin, because they expanded more and drilled a larger hole.

In those days velocities, all below 1600 f.s., were of relatively little importance. A case in point was that of F. C. Selous, the celebrated African hunter, and regarded as the greatest big game hunter who ever lived. At one time in South Africa he was in a locality where Cape Buffalo were very plentiful, and he had many natives to feed. He was using a .450 rifle shooting a 480 grain bullet, with a charge of 90 grains of Curtis and Harvey No. 6 powder, equivalent to a charge of about 120 grains of FG American black powder. Quite frequently the bullet would penetrate completely through the buffalo, as seen from the blood spoor, but fail to stop it. To avoid these occasional failures it occurred to him to reduce the powder charge to 70 grains, and these loads did not penetrate through so often, and killed better. (While loading these cartridges one day, he was smoking his pipe, and a spark fell in the powder, burning and poc-marking his face badly.)

Such cartridges, powerful as they were, did not prove heavy enough for elephant, rhinoceros, or for Asiatic buffalo and bison in thick cover, and for these the hunter of those days used an "elephant rifle," a double barrel weapon weighing about 15 to 20 pounds, and of 4 or 8 bore (.935" and .835") shooting 12 to 14 drams of black powder and 3 to 4 ounce bullets.

Enter now for the first time the individual called the "small bore crank," who has, and to this day continues to confuse the issue as to killing power to a deplorable degree. The favorite weapon of Mr. F. C. Selous for general shooting in Africa from about 1885 to 1895,

was a single barrel, falling block rifle of .450 bore made by George Gibbs, regularly shooting a bullet of 540 grains and a charge of 75 grains of Curtis & Harvey powder. One day with this rifle he killed six elephants, and in writing of the experience he stated "You can kill anything on earth with a .450 Gibbs rifle." This story ran like wildfire among sportsmen, and as a consequence a number of young and inexperienced hunters used such rifles for elephant, and many were the failures and deaths of the hunters.

About 1885 "Express" cartridges began to appear for black powder rifles. These were loaded with lighter bullets, about 300 to 350 grains in .45 caliber, and with a hollow point in the bullet so it would expand to larger diameter on striking or during its penetration. The velocity was higher also, about 1500 to 1700 f.s. These cartridges were supposed to be a great advantage because of the flatter trajectory and the greater diameter of the wound in the animal due to the expansion. But as a matter of fact the trajectory was not flattened enough to give any material increase in the sure hitting range, which still remained about 150 yards. And what the express cartridge gained in larger diameter of wound it seemed to lose in penetration. Also it was more difficult to make the light express bullet shoot as accurately as the heavier bullet. These light express bullets were fairly successful on the deer tribe, but they lacked the penetration for heavier American game, and the heavier game of other countries. At that time a very famous explorer and big game hunter, Sir Samuel Baker (with Speake the co-discoverer of the source of the Nile) was very insistent in his condemnation of express bullets. He believed that the deadliest projectile for game was the heaviest bullet of solid, soft lead that could comfortably be fired from the shoulder. Commonly he used 4 and 8 bore rifles for elephant and other thick skinned game, and for general shooting a double .577 bore shooting a bullet of 650 grains with 160 grains of Curtis and Harvey black powder. Baker had a special elephant rifle made for him by George Gibbs of Bristol, and which he termed "The Baby." It weighed 21 pounds with a 36 inch barrel, and shot a 4 ounce conical bullet with a powder charge of 16 drams. "An extraordinary success attended this rifle, which became my colossal companion for many years in wild sport with dangerous game." Of course it took a colossal man to handle such a weapon and to stand its recoil, and Baker was such a man. One day on the upper Nile two of his camp followers became obstreperous, and Baker proceeded to chastise them by lifting each completely off the ground at arms length and banging their heads together until they became good!

Coming back now to America, the most successful big game rifles of the black powder period, for *all* American game were the .45-70

and .45-90 Winchesters, and the Sharps rifles in corresponding calibers. The most celebrated American hunter of that period was Colonel William D. Pickett. He spent all his time from 1876 to 1883 hunting grizzly bears and other game in Montana and Wyoming. Most fortunately he was also a rifleman, and had been a celebrated long range shot before going West, and he has described his experiences in technical detail.* He used for all his hunting a .45 Sharps long range rifle, the cartridge being normally loaded with 90 grains of powder and a 450 or 520 grain bullet. He loaded all his cartridges, using Curtis and Harvey powder which he imported from England. As has been said, 90 grains of this powder gives about the same muzzle velocity as 120 grains of American FG black powder. With this rifle he shot literally hundreds of grizzlies, as well as a large number of wapiti, sheep, and deer, and a few buffalo.

At first he used heavy bullets of 450 and 520 grains, but later he loaded his cartridges with 110 grains of powder and either a 340 grain solid bullet, or a 240 grain hollow point bullet. The former, chronographed at Frankford Arsenal, had a muzzle velocity of 1830 f.s., and the latter 1910 f.s. Both these loads performed excellently on grizzlies. Here, for the first time, velocity is high enough to begin to show in increased killing power.

Between 1890 and 1896 most of the leading nations adopted the smokeless, small bore, high power military rifle in calibers from .244 to .319 inch, and with bullets weighing from 112 to 236 grains. Muzzle velocities were from 1960 to 2400 f.s., and the bullets were fully jacketed with cupronickel or mild steel. In warfare the wounding effect was much less than with the large diameter, heavy lead bullets that preceded them, even though the muzzle velocity was much higher. These military bullets were all formed with a round nose, and if they did not encounter large bones that caused them to turn over or disintegrate, they penetrated cleanly, making but a small hole. The majority of soldiers who were only wounded recovered very promptly. Wounds were usually sterile because the small bullet carried little clothing into the wound, and the jacketed bullet itself was extremely hot when it struck.† This was thought to be a military advantage in that a wounded soldier is more trouble to the enemy than a dead one. Of course this depends upon conditions. If a victorious army is advancing it is they and not the enemy who usually have to care for and feed the enemy's wounded.

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* "Hunting at High Altitudes," a book of the Boone and Crockett Club, Harpers, N.Y., 1913.

† Just as the above was being written the writer heard that his old captain, Major General Briant H. Wells, had been complaining of pain in his leg. He had the limb X-rayed and a Mauser bullet was discovered that had been there since the Spanish American War, 46 years ago.

Shortly after these bullets were adopted, British troops were engaged in considerable warfare with tribesmen of the Soudan and of the Northwest Frontier in India. These small bullets usually failed to stop charges of these fanatical natives, who, though shot completely through the body, continued to come on, fight, and kill the British troops. Accordingly expanding bullets with a hollow point, termed Dum Dums were developed for use in such warfare. This bullet, which is described in Volume I, expanded when it struck and caused a very extensive and fatal wound. It was soon prohibited in warfare by a clause in one of the Hague Conventions.

About 1905 the Germans changed their small bore military bullet, decreasing it in weight from 236 to 154 grains, and giving it a very sharp point, also increasing the velocity to 2800 f.s. This velocity, together with the sharp point, greatly flattened the trajectory and increased the danger space. Other nations quickly adopted this pointed bullet and likewise increased their velocity. These short "spitzer" bullets made much more serious wounds than did the older, long, round nose projectiles. Very often they did not penetrate straight through with a small hole as might be expected. Due to the sharp point the center of gravity was more to the rear, and the bullets, on striking very often turned over and penetrated more or less sideways instead of point to the front. The bullet thus twisted and "buzzed" through the flesh, causing extensive and serious wounds. Also the sharp point tended to follow the line of least resistance, and sometimes dived through at an angle, tending to aggravate the turning over. The very high velocity resulted in transmitting much energy to tissue, and particularly to bone particles which the bullet struck, and these in turn became projectiles which destroyed more tissue within several inches of the actual path of the bullet. Sometimes the area of lacerated tissue and the exit wound were four or five inches in diameter. Until their effect became well known, combatants would often accuse each other of using Dum Dum or explosive bullets.

With these full jacketed military bullets we now see velocity assuming much more importance, the wounding effect apparently depending on the following factors in the order of their importance:

1. Velocity.
2. Shape of Point.
3. Sectional Density.
4. Weight.
5. Diameter.

When the small bore, high velocity, military cartridges were introduced it became apparent that they had decided advantages for

sporting purposes, provided that a method could be devised to increase their killing power. Their high velocity, flat trajectory, better accuracy, lighter recoil, absence of smoke, and lighter weight of ammunition were great improvements over the black powder cartridges. The Dum Dum bullet pointed the way to their greater effectiveness on game. Expanding bullets were developed by inserting the lead core into the point of a jacket fully closed at the base, leaving a little naked lead exposed at the point. These were called "soft point" bullets, the point expanding on impact, and mushrooming so as to about double the effective diameter of the projectile. High power cartridges with soft point bullets, and rifles for them began to appear on the American market about 1896, and were so successful that within three years they had completely supplanted the black powder weapons.

Later some expanding bullets were made with a hollow point instead of a soft point—that is a jacket closed at the base, but a hollow in the tip that extended a short distance into the lead core. Later, in order to give the modern extremely sharp point, this hollow was filled with a small, sharp pointed, copper wedge, or with a hollow pointed tube of thin copper. Such bullets are completely described in Volume I.

It was soon found that these soft point bullets had to be of different weight and construction to be effective on game of different size and toughness. The .30-30 bullet of 160 grains at M.V. 1960 f.s., with relatively thin jacket and considerable lead exposed at the point, proved very effective on the relatively small and soft tissued deer of America.* But it very often tended to fly to pieces and not penetrate deeply enough on wapiti, moose, and large bear. On the other hand the heavier 220 grain bullets of our .30-40 Krag cartridge, and also the 215 grain bullet of the .303 British cartridge, with their thicker jackets, greater weight, greater sectional density, and less lead exposed at the point, proved very satisfactory in killing power for the larger American game as well as for the majority of the tougher African antelope.

During the period 1900 to 1937 a very lively discussion continued in the sporting press relative to the effectiveness of certain bullets and cartridges. All kinds of point construction and thickness of

* Over many years there has been much criticism of the effectiveness of the .30-30 cartridge on deer. It cannot fail to be apparent to anyone who has made much research into this matter that the psychology of the average American hunter is such that he is very prone to criticise failures, but takes success more or less for granted. For every hunter who has criticised the .30-30 there have been probably a hundred who have used it with perfect satisfaction and said nothing. In the past forty-five years there have been more deer killed in America with the .30-30 cartridge than with any other load, and it still remains the most commonly used cartridge for deer.

jacket were tried. None proved markedly better than the plain soft point with the amount of lead exposed in proportion to the expansion desired.

The high velocity, smokeless cartridge also soon supplanted the old 4 and 8 bore black powder cartridges for heavy, thick skinned dangerous game. The typical elephant rifle of today is one of .416 to .577 caliber, shooting a bullet weighing between 410 and 750 grains at muzzle velocities from 2100 to 2350 f.s. Full jacketed (solid) bullets are used for elephant and rhinoceros, and soft point bullets usually for buffalo. These are much more effective than the big bore black powder cartridges, the recoil is lighter, there is no smoke, and the rifles are much lighter—about 12 pounds.

There has been another development with regard to rifles for elephants which must be approached with considerable caution. Elephants are very dangerous animals, particularly when wounded. The only instantly fatal shot is that in the brain. Due to the extremely thick and heavy skull, the small brain can only be reached from the side, and the bullet must be placed at a point midway between the eye and the orifice of the ear, the "bullseye" not being more than five inches in diameter. Shot anywhere else in the head with *any* bullet it is extremely unlikely that the brain will be reached. Even for the side shot penetration of the bullet is important, hence full jacketed (solid) bullets are used. Professional elephant hunters, that is, men of great experience, skill, and coolness in the presence of danger, have found that it is easier to make a successful brain shot with a light, handy, and very accurate small bore rifle than with the usual heavy elephant rifle. Accordingly a number of such hunters have used rifles of .256, 7 mm, and .30 calibers for such shooting, always using the long, heavy, *round nosed* full jacketed bullet to give the necessary penetration. If such a bullet reaches the brain it kills just as surely and quickly as a much larger and heavier bullet.

But such rifles are good for this shot and for nothing else on elephant. If the brain is not reached, the wound is entirely ineffective. They are thus very dangerous rifles for the average sportsman to use, whereas the modern elephant rifle of .416 to .577 bore, if it does not kill instantly, will almost always stop or turn the beast long enough for the hunter to get in a second shot or to escape from a dangerous situation.

Incidentally an elephant rifle of .600 bore, shooting a 900 grain bullet has been advertised and described. It is doubtful if more than fifty of these have ever been built. The recoil is too great and the rifle too heavy in weight. But it is interesting as being the most powerful shoulder rifle produced to date.

Reverting again to the modern small bore rifle for medium game.

The increase in velocity from 2000-2300 to 2700-3100 f.s. greatly increased the effectiveness and killing power, but to some extent it also accentuated the difficulties with light weight, easily expanding bullets. At very high velocities these light bullets often flew to pieces almost at once on impact with the thicker skin and tissues, and heavier surface bones of the larger animals, making large superficial wounds, but completely failing to penetrate to vital organs. Heavier, tougher bullets were effective on the larger animals, but again these quite often failed on the smaller deer and sheep as they would fail to expand, penetrate cleanly, and make only small wounds. Some sportsmen also tried the full jacketed, pointed, military bullet in their high intensity rifles, but while these bullets frequently turned over on impact, made serious wounds, and killed well, they did not always do this. Sometimes they would penetrate cleanly, and sometimes they would dive off at an angle, and for sporting purposes reliability in killing power was most desirable.

Up to this point practically all the failures and complaints had occurred because the sportsman, either through ignorance or economy, had used the wrong bullet for the game he was hunting. Of course it might be said that the solution was to educate the public to use a different type of bullet for various sizes of game, just as the shotgun shooter has been taught to use different sizes of shot for different sizes of birds. But the psychology of the rifle hunter did not seem to work that way. The majority thought that when they bought a cartridge for their big game rifle it ought to be adequate for any game; surely if it killed a large animal it certainly should also kill smaller ones!

Accordingly, for the past ten years ingenuity has been directed towards developing a bullet which would mushroom easily even on the softer bodies of small animals, and yet would hold together, not fly all to pieces, but retain sufficient of its weight to penetrate deeply enough to reach the vitals on larger animals.

The first bullet that was eminently successful in this respect was the Peters Belted Bullet, developed about 1934, and described in Volume I. It had a thick belt of gilding metal just below the soft point which kept the jacket from splitting and the lead core from disintegrating. The soft, hollow point mushroomed promptly and invariably, but the remainder of the bullet of three-fourths of its original weight held together and penetrated deeply on large game. It was a very successful bullet, in .30 caliber and weighing 225 grains, alike on small deer and Alaskan brown bear, but it proved to be so expensive to manufacture that there was no profit in its sale, and it has now been replaced with the simpler Remington and Peters "Core Lokt" bullets of similar construction also described in Volume I. Another development is the Winchester and Western

"Silvertip" bullet with two jackets, the inner and thinner one designed to hold the core together even when it has expanded.

These new expanding bullets are all formed with a more or less round nose. Their trajectory over practical ranges is therefore not quite so flat as it would be did they have a sharp point, and the remaining velocity is likewise not quite so well sustained. The problem of developing an expanding sharp point game bullet which will be effective alike on medium and large animals remains to be solved—or does it?

One particular bullet apparently has been overlooked. The 130 grain Winchester pointed expanding bullet for the .270 Winchester cartridge, now obsoleted in favor of the Silvertip bullet of the same weight, was very remarkably successful on both deer and all the heavier American big game. The enviable reputation of the .270 cartridge was made by that bullet. Almost invariably it killed deer instantly. Someone once wrote that the .270 was a little light for the heavier game, and other writers with no experience whatever have copied that remark so often that it has been believed, but it is not so. A careful search of the records of this 130 grain pointed expanding bullet in the hunting fields will show that it also killed the largest game—wapiti, moose, and large bear—in a very reliable and satisfactory manner. It was also much more accurate than the great majority of sporting bullets, and its fine ballistic coefficient gave it a very flat trajectory with velocity well maintained. In fact it had a flatter trajectory over 300 yards than any other game bullet.

Probably also, because the other pointed expanding bullets, with the same construction of point were not quite as effective on game as was hoped, it was assumed that this 130 grain bullet likewise could be improved. But apparently no one has sectionalized this particular 130 grain bullet and noted that its construction was different from all other pointed expanding bullets. The jacket is extremely thick at the base, and the walls for a considerable distance above the base are very much thicker in proportion than any other similar bullet of the same make. It hardly deserved obsolescence, and it may point the way to a successful pointed sporting bullet.

To sum up, the factors which make for killing effectiveness in a high velocity expanding, sporting bullet in the order of their importance are:

1. Velocity.
2. Construction.
3. Sectional Density.
4. Weight.
5. Diameter.

But we should not dismiss these five factors without a little more discussion.

Velocity is of the greatest importance. Game is not killed at the muzzle, so of course we refer to striking or remaining velocity, and not muzzle velocity. A lead bullet, or a jacketed bullet with a lead point will not usually expand or mushroom on animal tissue at striking velocities under about 1300 f.s. unless it has a very open, hollow point with thin side walls. For this reason pistol bullets seldom expand materially on flesh. When the striking velocity reaches about 1800 f.s. the bullet begins to convert the bones and tissue that it strikes into quite efficient projectiles on their own account, and what we often term an "explosive effect" begins to appear. This explosive effect increases rapidly as the velocity increases. Apparently when the striking velocity reaches about 3500 f.s. a different and remarkable form of effect begins to appear, which as yet we do not understand. The writer once saw a prairie dog struck in the right fore paw at this velocity, and killed instantly as though it had been struck by lightning.

The construction of the bullet has already been commented on.

Sectional Density comes next in importance. This seems to be particularly true in connection with the killing power on larger animals, where deep penetration is needed. With the .257 Roberts cartridge, the 117 grain bullet at M.V. 2700 f.s. appears to be much more effective on game larger than deer, than the 100 grain bullet at M.V. 2860 f.s. The same may generally be said of the 150 and 130 grain bullets in .270 Winchester cartridge. The late Charles Sheldon used but one rifle for all his hunting over many years,—a .256 Jerrery Mannlicher shooting a 160 grain soft point bullet at M.V. 2300 f.s. With it he shot over five hundred head of American big game, including between seventy and eighty grizzly and Alaskan brown bears. He had no recollection of the bullet ever failing to kill well. This bullet has a larger sectional density than any standard American game bullet. In the .30-06 cartridge the increased effectiveness on wapiti, moose, and large bears of the 220 grain bullet, as compared with lighter ones at higher velocities, is well known.

Weight and Diameter, apart from sectional density, are important factors in bullets for small game as distinguished from those for big game, and in the latter as distinguished from those for thick skinned dangerous game. A light, .22 caliber bullet will probably never be satisfactory for big game, and it is doubtful if any .30 caliber bullet will ever be satisfactory for elephant and rhinoceros. Apparently from years of field experience the smallest bullet that has been satisfactory for these large beasts, at muzzle velocities from 2100 to 2350 f.s., is one of .416 caliber weighing 410 grains.

British Opinion. The British "Textbook of Small Arms, 1929" (p. 364) makes the following remarks as to wounding and killing power:

"But of all the factors which influence wounding power the velocity of the bullet is most important. It is intimately connected with that variety of wounds incorrectly termed 'explosive.' In these wounds there is commonly a small wound of entry in the skin and an enormous crateriform opening at the exit from which protrude masses of damaged muscle and other tissues with tendons and fibrous structures, all bound together by blood clot. Fragments of bone are often found among the lacerated parts and even outside the wound. The parts present, in fact, the appearance of having been subjected to the effect of a local explosion. The destructive effects, moreover, are observed at some distance from the actual track of the bullet. Small hemorrhages, separations of aponeurotic planes, laceration of muscle fibres, and destruction of cellular elements of glands have been observed an inch or more from the bullet track. There seems to have been a 'tissuequake' of more or less severity. These wounds have been observed in all campaigns since cylindro-conoidal bullets have been used. And the point which all military surgeons make in discussing their causation is that they are an effect of great velocity. They are produced at ranges which are short for rifles with a comparatively low muzzle velocity, and which increase as the muzzle velocity increases. They came therefore particularly under notice in the South African war (1900-1902) and have increased in number in every succeeding campaign in association with the rising muzzle velocity of military rifles. The Martini-Henry and the Gras rifle caused explosive wounds up to 150 or 200 yards, while the Lee-Enfield and the Lebel caused them up to 300 or 400 yards. With the pointed bullet probably another 200 yards may be added.

"These wounds are commonly observed in association with bone injury. The explanation of their cause in this case is quite simple. The bullet impinging on a hard substance like bone, breaks up the bone into fragments, large and small, and then imparts some of its energy to these fragments, so that they become secondary missiles and magnify the destructive thrust of the bullet through the tissues. It is not at all necessary that the bullet should break up. It is only necessary that it should possess sufficient velocity.

"But a far more interesting class of explosive wounds is seen in association with soft parts only. Here the 'secondary missile' explanation hardly seems sufficient. With sporting rifles using ordinary soft nose bullets explosive effects were first observed on animals when the Roumanian Mannlicher was introduced firing a bullet with a muzzle velocity of 2300 f.s. and falling 100 f.s. per 100 yards. Now many sportsmen had used the British service rifle and Mark VI ammunition with a muzzle velocity of 2000 f.s. without bursting their game. So it might seem that there is a critical

velocity somewhere between 2000 and 2300 f.s. where bursting effect begins. It has been suggested that the rush of air following the bullet may be likened to the cavatational velocity with which air rushes in to fill a vacuum, and when this velocity reaches a limit somewhere beyond 2100 f.s. it becomes competent to produce disruptive effect on the tissues. More probably, however, there may be in the tissues themselves a commotion in the wake of a high velocity bullet comparable to that producing cavatational velocity in the air, and tending to produce a blowing-out effect at the exit, and some disruption result in the near vicinity of the track.

"To sum up, the wounding effect of a small arm missile is partly due to the nature of the part struck, partly to the shape and structure of the missile, and chiefly to the velocity which it possesses on impact. The marked loss of 'stopping power' of the non-deformable blunt-nosed .303 bullet, as compared with the leaden deformable bullets of larger caliber, has been quite regained by the pointed bullet.* Experience of wounds in the Great War has shown that as an effect of increased velocity, explosive wounds are seen up to ranges of 600 yards, and, as an effect of increased instability of the bullet after impact, all wounds show a higher degree of laceration of soft parts with finer comminution of bone, whether compact or cancellous."

Shock

Sportsmen speak of shock in relation to killing power. They loosely describe certain cartridges as being excellent or deficient in "shocking power." What is shock? The writer has questioned many eminent physicians and none will venture to define shock. But with relation to wounds one and all seem to agree that that physical occurrance which we commonly term "shock" bears a very close relationship to the amount of bodily tissue destroyed. But even the extent of the wound is not a sure indication of killing power for the injury may be very extensive and yet more or less superficial, not reaching to vital organs. Also some animals appear to be so phlegmatic as not to be susceptible to shock. In addition, an animal whose instincts of self preservation or fighting instinct is aroused by having been alarmed by the hunter, that is having sighted, scented, or heard him, or by a wound, is less susceptible to shock, apparently,

* The .303 British Mark VI 215 grain blunt nose bullet has a muzzle velocity of 1970 f.s. The present .303 British Mark VII 174 grain pointed bullet has a muzzle velocity of 2440 f.s. It is not believed that the writer of the above intended to indicate that the pointing of the bullet alone produced increased wounding effect. At higher velocities, however, the pointed bullet, by reason of its instability does often produce more lacerating effect than a blunt nose bullet of equal weight and velocity.

than one who receives shock from the first shot placed before it was aware of the presence of the hunter. Thus many animals, having been wounded, apparently pay little or no attention to subsequent wounds unless they are in parts almost instantly fatal.

In the opinion of the writer the matter is rather simple. The introduction of "shock" into a discussion of killing power is unnecessary, and does not clarify it. Aside from those bullets which enter the brain, the spinal column, or the aorta and kill instantly, the killing power of any bullet is in direct proportion to the average amount of vital tissue that it destroys, and that in turn depends upon the various factors listed above under various bullets at low velocity, military bullets, and expanding bullets at high velocities.

Penetration Tests

Many years ago the Winchester Repeating Arms Company standardized a penetration test. The target consisted of 7/8" pine boards, held one inch apart, and placed fifteen feet from the muzzle of the gun. For many years they published tables giving the penetration of various bullets on this target. Their ballistic table of 1907 given in the appendix contains the last of this penetration data. They state quite properly; "Penetration is not the measure of striking energy. As an illustration take the figures in our tables for the .30-30 Winchester Center Fire cartridge. With the soft point bullet the penetration is but 11 boards, whereas that cartridge with the full metal patched bullet will penetrate 42 boards. The energy of both is the same. All other things being equal, the bullet which resists deformation will give the maximum penetration. The soft point bullet, which generally stops under the skin of the animal, delivers its whole energy; while the full metal patched bullet, which passes through the animal, may make a less severe wound. Penetration, therefore, is not a good test of killing power. If the target is harder or softer than that described in our tables, the results obtained will not be the same, nor will the comparative results show corresponding differences."

Composite targets to more nearly represent animal tissue have been tried, such as one composed of leather to represent the skin, bones, and soap to represent muscular tissue. Very little was learned from such targets.

Military cartridges have also been tested against cadavers, and sporting cartridges on dead animals of various sizes, and on living but chloroformed animals to determine the effect on living tissue. Such tests give better indications but are expensive.

The following penetrations of our service rifle cartridges have been determined officially:

.45-70 Springfield Rifle, 500 grain bullet, 16 parts lead to 1 part tin. Penetration in white pine.

Rifle, 32.6" barrel, M.V. 1315 f.s.	100 yards	19.1	inches
	500 "	10.6	"
Carbine, 22" " M.V. 1150 f.s.	100 "	14.5	"
	500 "	7.25	"

.30-40 Krag. 220 grain full jacketed bullet, M.V. 2000 f.s.

Material	*Range*	
	50 feet	*100 yds.*
	Inches	*Inches*
Moist sand in box of 7/8" white pine boards*	5.5	12.8
Dry sand in bags	5	6
Loam nearly free from sand, cast up in form of a parapet	6	13.5
Boiler-plate steel, 0.5 inch thick	0.13	
Low steel plate, .375" thick	Through	
Low steel plate, .287" thick	Through	.1" @ 100 yds.
High steel plate (as rolled) .153"	Through	

* Penetration in sand at 50 feet is always less than at long ranges. Owing to high velocity of bullet at short range, the particles of sand struck do not have time to admit of motion among themselves before the bullets are completely destroyed.

.30-06 Springfield, 150 grain pointed, full jacketed bullet at M.V. 2700 f.s.

Material	*Range*		
	200 yards Inches.	*400 yards Inches.*	*600 yards Inches.*
Low steel, ¼" plate	Through	Through	0.1
Low steel, ½" plate	0.15	0.0	0.0
Trap rock, between 1" boards	3.2	3.2	2.6
Trap rock in sack	3.22	3.56	2.72
Loam between 1" boards	7.0	14.4	9.4
Sand between 1" boards	4.0	5.8	8.52
Sand, loose dry	8.1	—	12.3
Coal, hard, between 1" boards	5.2	4.8	5.2
Brick (cement mortar)	2.2	1.56	1.16
Solid oak	32.05		
Oak, 1" boards	26.46	17.96	12.46
Pine, yellow, 1" boards	25.72	17.8	13.0
Pine, white, 1" bds. @ 50 ft.	59.9		

Killing Effect of Various Cartridges

The best indication of the killing power of a cartridge on game is the average result it has given in the hands of many sportsmen over a long period of years, American and British sportsmen have been in the habit of reporting the results they obtained in their hunting with various rifles and cartridges, and these results have been published in their books and magazine articles from time to time. The writer has taken the trouble to collate these reports over a period of fifty years. He believes that he has thus examined approximately fifty percent of the reports that have been published in the English language. It has been necessary to discard many such reports because of inaccuracy or unreliability. The integrity of the reporter has not been questioned, but his ability to observe accurately, his experience, and his marksmanship have been considered in giving weight to his testimony. The results are summed up in the following notes on the killing power of the more common American sporting cartridges. Humane killing power only is considered—not ability to hit:

.22 Long Rifle, Solid Bullet. Suitable for rats, starlings, sparrows, gray squirrels, and weasels (ermine). It is much used in the North for shooting grouse and ptarmigan on the ground and in trees, and is usually fairly satisfactory for this, although there will be cases where the birds, undoubtedly well hit through the body, will fly right off.

.22 Long Rifle, High Velocity, Hollow Point. The expanding bullet is much more destructive on animal tissue than the solid bullet as can easily be told by shooting into bars of laundry soap. But this cartridge has been very much over-rated. See under the paragraph *.22 Rim Fire in General.*

.22 Winchester Rim Fire. This cartridge is noticeably slightly more powerful than the two preceding. In recent years the high velocity type has been very greatly improved in accuracy and reliability. With solid bullets it is a very fine cartridge for gray squirrels, grouse, and weasels, also for cottontail and showshoe rabbits. It is also a fine trapper's cartridge for, being inside lubricated, it can be carried loose in the pocket, the trapper can kill birds and small animals for the pot and bait, and he can also dispatch trapped animals with brain shots without injuring pelts. The hollow point variety, however, simply destroys meat and fur without being really powerful enough for any larger animals than those above.

.22 Rim Fire in General. Except as noted above, these cartridges have been very much over-rated as game cartridges. Particularly the advertisements featuring them as suitable for woodchucks and other predators have been very misleading, and not in keeping with the

FIGURE 20

The Remington Arms Company Chronoscope, Type GA (Galvanometer Type), operates similar to the Condenser Chronoscope in that the unknown time interval is measured by means of a constant current of known magnitude. The difference lies in the fact that in the Galvanometer Chronoscope the time interval, which is proportional to the length of time the constant current has flown, and hence to the quantity of charge carried by the constant current, is measured by the throw of a ballistic galvanometer. This instrument does not supply a permanent reading, but is quite rapid and very useful for the measurement of such quantities as barrel times.

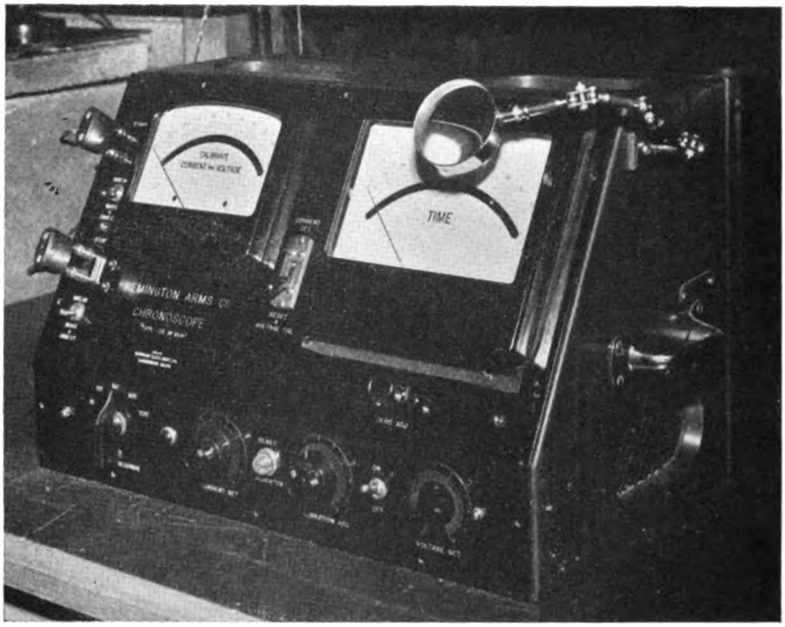

FIGURE 21

The Remington Arms Company Chronoscope, Type CR (Condenser Type), is a portable instrument for use in measuring short time intervals in the range between one milli-second and two-hundred milli-seconds. The instrument as supplied will give a semi-permanent indication, but with the addition of a suitable recorder it can also provide a permanent record of the measured intervals. The principle of operation consists of charging a condenser at constant current during the unknown interval and measuring the resulting voltage in terms of time. The instrument consists of three circuits as follows:

A thyratron switching circuit which produces a pulse to start and stop the charging current of the condenser at the beginning and end of the interval being measured.

A constant current condenser charging circuit.

A vacuum tube voltmeter circuit connected directly across the condenser.

The input of the thyratron switching circuit is designed for operation directly from either "make" or "break" circuits, or from an external source of voltage such as the coil disjunctor.

experience of hunters who have used them extensively. Many young sportsmen have taken the writer to task for stating that he did not consider the .22 high velocity cartridge with hollow point bullet satisfactory for woodchucks. But it is remarkable how many of these young woodchuck hunters have taken the writer's advice and turned to the .22 Hornet cartridge, and then have written that he was correct, and that to their chagrin they found that many of the shots with the .22 rim fire hollow points which they took to be misses, must have been hits, and the chucks got into their holes to die a lingering death because of the lack of killing power.

On wild turkeys entirely too often the experience has been that, when fairly struck with the .22 high velocity hollow point bullet, this fine bird will sail or run off into thick, impenetrable cover and die for the raccoons and buzzards to get.

The prairie dog is about as tough a little animal as the writer knows of. Shooting them with the .22 Hornet cartridge, he has frequently had them crawl twenty five feet into their holes when almost cut in two. The rim fire .22 hollow point bullet is very inhumane for them. Anyhow, prairie dogs and the large Western ground squirrels are seldom to be approached as close as 60 yards, and over that distance, due to the trajectory and accuracy of the rim fires, it is almost impossible to place the bullet in a really vital spot. The .22 Long Rifle cartridge has made a fine reputation for accuracy in target shooting, where fouling and warming shots are always permitted before starting the record score. But when the cartridge is fired, as it almost always is in hunting, from a clean cold, or a fouled cold barrel, the accuracy is rather mediocre.

The shooting of ducks and geese with the rifle is prohibited in the United States, but it is sometimes done, although the writer should not be understood as encouraging it in any way. But in the wilderness of the Far North where shotguns are seldom carried, due to weight and bulk of ammunition, but where almost everyone has a .22 pot gun in addition to his big game rifle, geese and ducks are often shot with the .22 to augment the food supply. Of course, hit in the head or neck they are killed at once, but as usually hit in the body, they will frequently fly right off. Geese are highly gregarious and with their dying breath they will go right along with the flock.

But, despite all this, the .22 rim fires will continue to be used, particularly on the farm, in the wilderness, and on the edges of the wilderness for small game and pests. No other rifle or cartridge will quite take its place. Its great advantages are low cost, light weight, and availability of the cartridges, and particularly in some localities, lack of noise. But shooters should appreciate its lack of killing power and its short accuracy range, and should take extreme pains to place their bullets.

Except for the fact that their low velocity precludes long range hits, the low power .25-20 and .32-20 cartridges with solid bullets are fine for the larger edible birds such as wild turkeys and geese. The high velocity cartridges of these calibers spoil too much meat. On woodchucks and jackrabbits the high velocity .25-20 and .32-20, and particularly the .22 Hornet are fine, but here we do not mind the destruction of meat and pelts, a consideration which should always be taken into account.

Further along the writer has suggested that cartridges like the .22 Hornet, .22-3000 Lovell 2-R, and .22 Varminter may be loaded with non-expanding bullets and to velocities around 1500 to 1800 f.s., and used for small animals and birds where destruction of meat and pelts is undesirable. To some extent these also lack the desired killing power. One hunter of the writer's acquaintance used the .250-3000 Savage cartridge with an 87 grain full jacketed, pointed bullet at M.V. 1400 f.s. for small game on a long expedition where he had unlimited opportunity to observe its effect, and found it very lacking in killing and stopping power.

On the other hand, in his .30-06 rifles, the writer has used a reduced load consisting of the 150 grain full jacketed, pointed, service bullet loaded to 1550 f.s. for small game over a period of thirty five years, and it has been entirely satisfactory on geese, ducks, turkeys, rabbits, otter, beaver, agouti, coati, iguana lizard, etc. Evidently the larger hole made by the .30 caliber makes up for the deficiencies of the non-expanding very sharp pointed .22 and .25 caliber bullets. He has not tried this load on woodchucks, foxes, or coyotes, and does not believe it would be quite satisfactory on them.

.25 Stevens Rim Fire. Slightly more powerful than any of the above rim fire cartridges. With hollow point bullets it is the lightest cartridge that can be considered humane on woodchucks. With solid bullet is it not too powerful for squirrels and grouse, considering that these are being shot for the table.

.22 Hornet and .218 Bee. Soft point or hollow point bullets. Very satisfactory on woodchucks and fox to 200 yards. Too destructive for tree squirrels and grouse. Very satisfactory for wild turkey and geese when loaded to M.V. 2400 f.s. Not satisfactory or humane on coyotes.

.22-3000 Lovell, Lovell R2, and .219 Zipper. Noticeably more powerful than the Hornet and Bee. Suitable on woodchucks to about 275 yards. In only about 50 percent of the shots on coyotes does it kill well.

.220 Swift and .22 Varminter. Suitable for woodchucks, fox, coyotes, jack rabbits, and eagles to about 350 yards. With 55 grain bullets at maximum velocities is suitable for deer and wolves to about 150 yards.

.25-20 Single Shot and Repeater. With 60 or 86 grain bullets. Same as .22 Hornet.

.25-35-117 Winchester. This cartridge, and the .38-40-180 are regarded as the lightest cartridges that are satisfactory and humane for deer, and this only to about 150 yards and then only in the hands of a skilled marksman.

.250-3000 Savage. With 87 grain bullet very satisfactory for deer to about 200 yards, but the 100 grain bullet is noticeably better, and also satisfactory for mountain sheep.

.257 Roberts. Similar to the .250-3000 Savage. With 100 grain bullet very suitable for deer, sheep, and antelope to about 225 yards, but hardly beyond. With 117 grain bullet its satisfactory killing power is extended probably to about 275 yards, and with this bullet there are many records of its having been used satisfactorily for wapiti and moose at slightly shorter distances, but it is generally regarded as too light for these animals.

6.5 mm Mannlicher (.256). With 160 grain bullet at M.V. 2300 f.s. has made a tremendous reputation all over the world on all but the largest soft skinned animals. Has sometimes proved unsatisfactory on wapiti. But in very short barrelled rifles the velocity is so reduced that it approaches the killing power of the .30-30 Winchester cartridge.

.270 Winchester. With 100 grain bullet is suitable for deer to possibly 250 yards. With 130 grain bullet is eminently and outstandingly successful for deer, mountain sheep and goat, and caribou to 300 yards, giving a very large proportion of instantaneous kills. Also suitable to 200 yards on wapiti, moose, and large bear. With 150 grain bullets same as 130 grain, but not such a large proportion of instantaneous kills.

7 mm Mauser. With 175 grain bullet similar to the 6.5 mm Mannlicher, except the more recent loadings to M.V. 2460 f.s. will be found noticeably more powerful.

.30-30 Winchester, .32 Special, and .303 Savage. 160 to 190 grain bullets. Satisfactory for deer, sheep, goat, antelope, caribou, and black bear to about 200 yards.* Its reputation on larger game is that it usually takes two or more bullets to kill unless the range is under 50 yards.

.300 Savage. Satisfactory for all medium sized animals to about 250 yards, and on the larger American mammals to about 150 yards. Hardly satisfactory on Alaskan brown bear. It is not certain that the

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* This statement should not be misconstrued. It and similar remarks in this tabulation refer to the killing power of the bullet only. It should not thereby be inferred that rifles for these cartridges will assure a good shot of hits in the vital parts of animals at the extreme ranges given when he does his part correctly. Accuracy, flat trajectory, and many other matters enter into that problem.

180 grain bullet is superior to the 150 grain. The very great popularity of this cartridge lies in its being the closest approach to the .30-06 cartridge that can be obtained in a lever action rifle.

.30-40-220 Krag. This cartridge was very extensively used on all American big game from 1898 to 1907, and proved entirely satisfactory on all species; on the smaller animals to probably 300 yards, and on the larger to about 200 yards. With lighter bullets the cartridge is about in the class of the .300 Savage.

.30-06 U.S. The 150 grain bullet at M.V. 2960 f.s. is very satisfactory for deer, sheep, goat, caribou, and black bear to 300 yards. At about 150 yards and under it gives a very large percentage of instantaneous kills on these animals when the bullet enters the chest cavity. On wapiti, moose, and grizzly bear it is fairly satisfactory to about 200 yards. Not regarded as suitable for Alaskan brown bear.

With 180 grain expanding bullets at M.V. 2700 f.s. it is very suitable for all American big game to 350 yards. A very satisfactory cartridge, and time tried in the hands of many prominent sportsmen.

With the 220 grain bullet at M.V. 2300 f.s. and over it is regarded by many as a little more reliable than the 180 grain bullet on wapiti, moose, and large bear.

.300 H & H Magnum. Same as the .30-06 but regarded as satisfactory to about 75 to 100 yards longer ranges. At all distances it shows very slightly greater killing power than the .30-06.

.303 British. Almost precisely the same as the .30-40 Krag with bullets of approximately the same weight.

.33 W.C.F. Same as .30-40 Krag.

.348 Winchester. The 200 grain bullet is much preferred to that of 150 grains, and has proved entirely satisfactory for all American big game to 200 yards at least, which is about its sure hitting range. The new 250 grain Silvertip bullet will possibly prove satisfactory to 150 yards on Alaskan brown bear. With either weight bullet a very satisfactory game cartridge at medium ranges.

.35 Remington. With 200 grain bullet has proved satisfactory for all American big game to 200 yards.

.35 W.C.F. Same as .348 Winchester with 250 grain bullet.

.38-55-255, .40-70-330, and .32-40. All black powder cartridges. Just prior to the introduction of high power cartridges the .38-55-255 cartridge attained great popularity in the eastern United States for deer. It was remarkably successful on these easily killed animals. Of course its good killing range as well as its sure hitting range did not exceed 150 yards. It was definitely a poor cartridge on moose. In the West, for medium sized game, cartridges approximating the .40-70-330 Sharps were very popular, such as the .40-82-260, .38-72-

275, .40-70-330 Winchester, and .40-72-330 Winchester, but one and all were considered light for wapiti and grizzly. The .32-40-165 cartridge also attained considerable popularity in the East for deer, but not to the extent of the .38-55. When a young boy the writer well recollects a discussion that ran for months in the sporting journals, as to whether the .32-40-165 or the .45-90-300 was the better cartridge for deer. Neither side won their point conclusively, but at least much evidence seemed to prove that the .32-40 was an entirely satisfactory deer cartridge. Those who believe that the .30-30 is not powerful enough for deer should note this. Both cartridges have bullets of approximately the same weight and diameter, but the muzzle velocity of the .32-40 is 1400 f.s., and that of the .30-30 2200 f.s.

.375 H & H Magnum and .405 Winchester. It goes without saying that both of these cartridges have absolutely ample killing for any American game. In fact the power seems to be excessive, entailing needless cost and recoil, except that for Alaskan brown bear in the southeast portion of their range, where the cover is thick and distances often very short, they may be indicated. Both seem to be more suitable for Africa and India than for America, but neither should be regarded as suitable for elephant or rhinoceros.

.45-70 and .45-90. These black powder cartridges have been commented on very fully at the beginning of this chapter.

Revolver Cartridges. The .38 Smith and Wesson Special cartridge with its common 158 grain round nose bullet is notoriously deficient in stopping and killing power. In fact even on grouse it merely drills a small hole and does not spoil an appreciable amount of meat for the table. With the Colt variety of bullet, which has a flat point, the stopping power is much better, and is sufficient for police purposes.

A slightly lighter cartridge, the .38 Long Colt, was used in the United States Army at the start of the Spanish American War and proved entirely inadequate for the fanatical Moros in the southern Philippine Islands. This finally led to the adoption of the .45 Colt Automatic cartridge, the .45 Colt revolver being used as a stop-gap.

The **.357 S & W Magnum** cartridge is usually regarded as having more killing power than any other revolver cartridge, but this is regarded as questionable. Its 158 grain lead bullet has a muzzle velocity of 1510 f.s. in a barrel 8½ inches long. A reduced load of those characteristics in a .35 caliber rifle would be regarded as a small game load.

The writer rather inclines to the opinion that the .45 caliber Colt revolver cartridge, with the older loading of 40 grains of black powder, and 255 grain flat point lead bullet, M.V. 910 f.s., was and is the most powerful revolver cartridge. In a great many instances it has killed deer and American mountain lion very effectively at short revolver ranges. It is also possible to hand load other .44 and

.45 caliber revolver cartridges with a similar charge. But a revolver or pistol should never be regarded as a satisfactory or humane weapon for big game, or even as a safe weapon for personal protection against dangerous game at close quarters. It is essentially a military and police weapon.

CHAPTER IX

Testing Ranges, Rests, and Records

FOR experimental work and tests in exterior ballistics certain facilities and equipment are necessary. The most important of these is a rifle range. A range for this purpose is not difficult to obtain, except close to large metropolitan areas. Even adjacent to large cities a military rifle range, or the range of a civilian rifle club is often available.

It is comparatively easy to obtain and equip a range suitable for ballistic work in any farming country, as nothing very elaborate is needed. Where only such shooting is contemplated, elaborate arrangements for safety are not essential, for the experimenter can be relied on not to discharge arms promiscuously or accidentally, and all projectiles can surely be confined to the backstop. For some years the writer conducted all his work on a range that had nothing for a backstop except a cribbing of posts and boards five feet high and six feet wide, filled with earth three feet thick, and 200 yards in rear of it was a used highway. No bullet ever missed the backstop. But a little more of the safety element than that would be desirable in many places.

For ordinary ballistic work a range which will permit of distances from 12½ to 300 yards inclusive will answer almost all requirements that are not of strictly military character. As a matter of fact, except for long distance trajectory and wind tests, almost everything can be accomplished on a one-hundred yard range. For screen shooting it is desirable that the range be fairly level, but otherwise the ground can be quite a little undulating provided, of course, that all targets can be seen from the firing point. On a farm it is not essential that the ground be taken completely out of cultivation, as the firing point and targets can be raised so as to fire above low growing crops.

The direction in which the range faces is important because work that requires critical aiming is difficult if the targets are in shadow. Thus a range that faced west could be used only in the morning. One facing north is good, but a southern facing is almost prohibitive. "North by East" is the ideal direction.

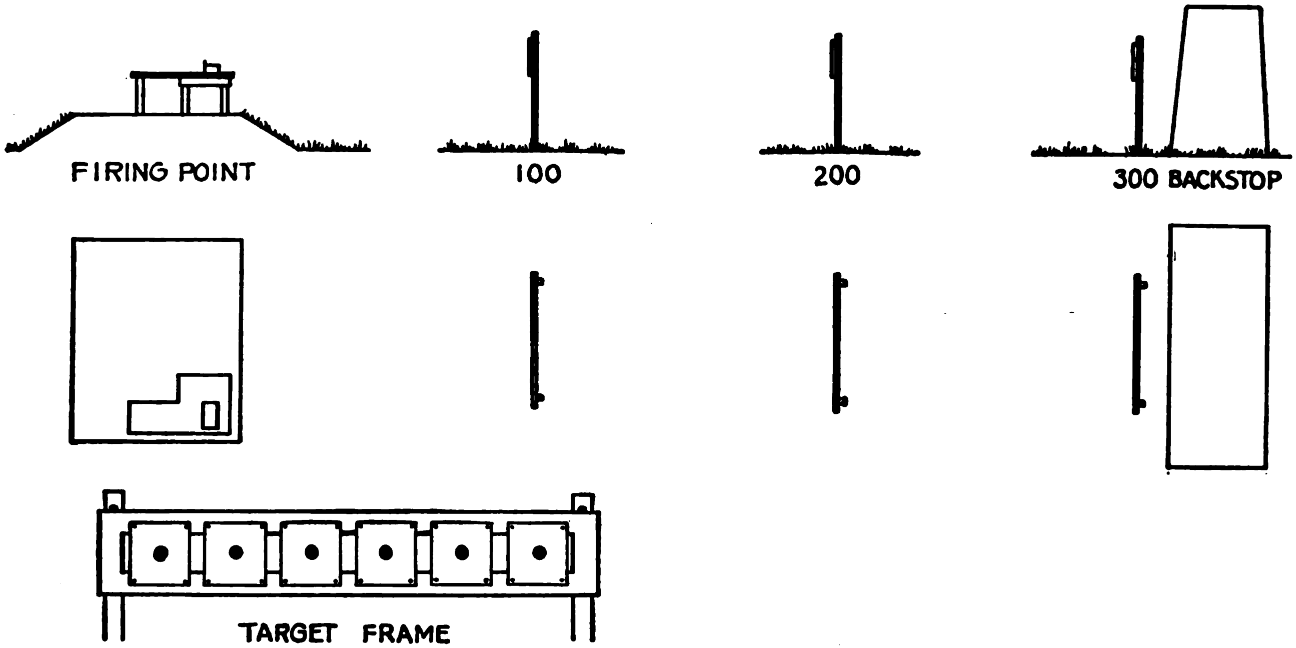


FIGURE 39

Details of a simple, easily constructed rifle range for ballistic experiment, accuracy testing, and determination of zeros; showing side and top views of raised firing point with bench rest, posts on which to hang target frames, and backstop. At the firing point there is space for shooting in the prone, sitting, kneeling, and standing positions alongside the bench rest.

The targets are tacked on a target frame of ⅞″ boards, and the frame is hung on the two posts at the desired distance. There being nothing behind the center portion of the paper targets, light shines through the bullet holes in the black bull's-eye and makes it easier to see the holes through the spotting scope.

A military rifle range has quite elaborate equipment such as butts, a pit for markers, sliding target frames, and telephone communication between firing point and butts. Nothing so extensive is necessary for individual experiment. Small ranges are based on the use of spotting telescopes at the firing point, by means of which all bullet holes can be seen in the target. Thus markers at the targets, elaborate butts, and sliding target frames are not necessary. This cheapens construction, and a very suitable small range can be laid out with nothing but a few cheap boards and posts.

Firing Point. It is sometimes desirable to raise the firing point two or three feet above the natural surface of the ground. The earth can simply be thrown up in a parapet and levelled off. This makes it unnecessary to do much grass cutting between firing point and targets, and it is even possible to raise low crops on the ground between. A firing point six by twelve feet, and level on top, with a grass or sod covering is best for a range for one to four individuals. Six feet square will provide room for assuming the various firing positions when the rifle is held in the hands, and a bench or other rest can be erected alongside. See Figure 39.

Target Frames. At each target position, say at 12½, 25, 50, 100, 200, and 300 yards, two stout posts can be set firmly in the ground. Target frames as shown, on which the standard targets are tacked, can be hung on these two posts so that they are high enough above the ground to be seen from the firing point. It is convenient to have the target frames of such length that they will accommodate at least five paper targets, which will give enough for several hours of shooting without having to visit the targets again to tack up more.

Backstop. Behind the target at the longest range, and so positioned that the bullets fired at any target will be stopped by it, there should be a backstop. Of course, if one controls all the land in rear of the targets to the full extent of the range of the rifle being used, or if there is a steep hill in rear, no artificial backstop is necessary. Otherwise where we do not have to provide for untrained and undisciplined shooters, a simple backstop can be erected at little or no expense. Long posts can be set in the ground, and planks nailed to them, making a crib three feet from front to rear, and two feet higher than the top of the highest target. This crib can then be filled with earth, sand, and rocks. No rock should fill closer than within a foot of the top, and from there up nothing but clear loam or sand should be filled in so as to avoid richochets from the top surface. Eventually the planks on the face of the backstop will be shot away in spots, when boards can be simply nailed over these spots.

Winter Ranges. The writer has two ranges of the above type, a winter range outside of Washington, D.C., and a summer range on his farm in New England. On the winter range the firing point is

inclosed in a small frame house that can be heated with a stove. There are two bench rests, and also space for firing standing or prone. Figure 40 shows the outside of this house with two ports or windows for the bench rests, and the upper standing port and the lower prone port. The frontispiece to Volume I was taken inside this house. Here shooting can be done all winter long in perfect

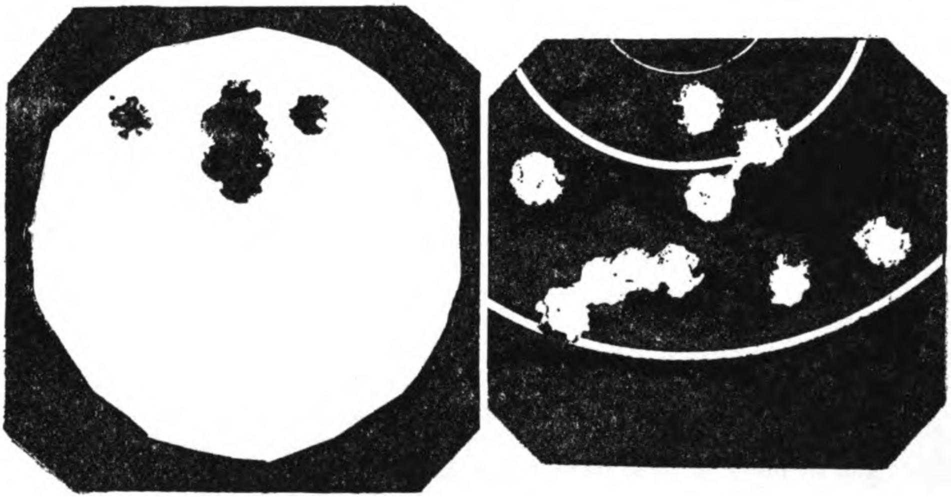


FIGURE 41

Both groups were fired at 100 yards in the process of zeroing rifles and testing them and their cartridges for accuracy.

The left group, ten consecutive shots, was fired with a Sharps-Borchardt rifle with Hyde medium weight barrel, 15 inch twist, .2235-inch groove diameter, for the .22-3000 Lovell R2 cartridge. The load was the 47 grain Wotkyns-Morse 8S bullet, 15.5 grains du Pont No. 4227 powder, and Winchester No. 116 primer. The firing was from bench rest. The 100 yard N.R.A. target had a 2¼-inch white center pasted over the black bullseye to permit accurate centering of the crosshairs of the 8 power telescope sight. The scope was adjusted so as to cause the group to center one inch above the point of aim (center of white plaster). Actually it centered .7-inch high. This group measures .94-inch extreme spread, and is indicative of the fine accuracy of the R2 cartridge in a good rifle.

The right group, also ten consecutive shots, was fired with a .30-06 Springfield sporting rifle with Remington 220 grain Core-Lokt factory ammunition. The rifle had a 2¼-power Zeiss Zielklein big game hunting scope with flat top post reticule, and aim was therefore taken at 6 o'clock on the 6-inch bullseye of the standard N.R.A. 100 yard target. The scope had been zeroed to strike the point of aim at 200 yards when fired from bench rest, and so should have struck 2½ inches high had it been fired here from bench rest. But this group was fired in the prone position with tight gunsling, and this so changed the jump and vibration as to cause the group to center only 1½ inches above the point of aim. The extreme spread of the group is 1.83 inches.

comfort, and with arms and ammunition at warm temperatures.

Targets. The standard six foot high military targets are unnecessarily large and expensive. For many years the writer has used with great convenience the Official National Rifle Association Small Bore Targets. They come in different sizes for 50 and 75 feet, and for 50, 100, and 200 yards. The 200 yard target is large enough for 300 yards, or even for 400 yards with a telescope sight. One great convenience is that the scoring rings are just one minute apart, permitting one to adjust sights with certainty, and to judge the size of the group when the bullet holes in these targets are viewed through a spotting scope. For use with telescope sights having cross hair or center dot reticules it is convenient to cut a circle the size of the 10-ring from a sheet of white paper and paste it over the 10-ring on the face of the target. The reticule can then be seen and centered clearly on this white center. See Figure 41. If a special target is desired it can be drawn in ink on the plain back of these targets. Targets are simply tacked on the wooden frames that are hung on the posts at the target location. Write the National Rifle Association, Scott Circle, Washington, D.C. for the address of the nearest retailer of these targets.

For patterning shotguns ordinary light brown "kraft" wrapping paper which comes in rolls 42 inches wide can be used. All targets should be on a non-gloss paper that is not pure white, so they will not reffect disagreeable light back towards the shooter, making it difficult to clearly define the sights.

Spotting Scopes. For use on such a range as we have been describing, a spotting scope is a necessity. It avoids time-consuming trips from the firing point to the target, and shows one at once just where his shot has struck, making a marker unnecessary. Any large telescope of fairly high power will do provided it will show .22 caliber bullet holes in the black bullseye at 100 yards, and .30 bullet holes on the white target surface at 300 yards. It usually takes at least a 20 power telescope with a large object lens to do this. The prismatic spotting scopes manufactured by the Argus Company and Bausch and Lomb are most convenient. To hold the telescope conveniently and trained on the target, the telescope stands sold by dealers in rifleman's supplies are desirable.

Machine Rests

For ballistic experiments, and for accuracy testing, some form of rest which will hold the rifle steady and aimed at the target is very necessary in order that the human element, always present when the rifle is held in the hands, can be eliminated. It is desirable here to state that no good results can be obtained by securing the rifle in a

vise. The rifle, no matter how light its cartridge, must be free to move to the rear in recoil.

Generally speaking there are two forms of rests. One permits the rifle to be returned to a constant and correct firing position after each shot has been fired, thus making it unnecessary to re-aim the rifle for the entire string of shots. The other holds the rifle steady for each shot, but requires it to be aimed afresh each shot. This form eliminates errors of aim only when a high power telescope sight is

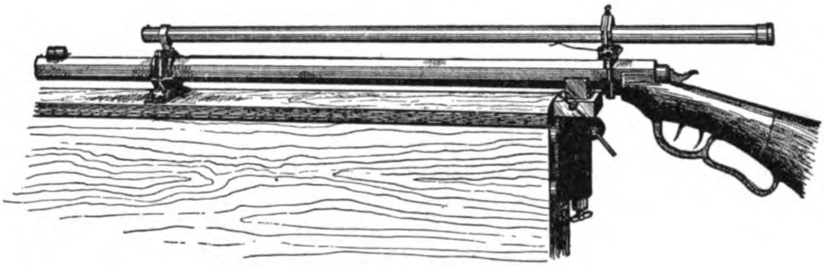


FIGURE 42

The Pope Machine Rest. Suitable for use with the older types of single shot rifles with heavy barrels, using cartridges of light recoil only. The forearm must be removed from the rifle before placing it in the rest. Not adaptable to modern bolt action rifles.

used for aiming. Both forms should hold the rifle so firmly that the possible disturbing element of a poor trigger squeeze need not be considered.

Many shooters believe that any rifle can be shot or tested in a machine rest that will eliminate the human element. This is not so. Machine rests are very limited in their application to rifles of various models, are rare, and many of them are very expensive.

In the days of single shot, black powder rifles having heavy barrels, a simple machine rest was in use. That manufactured for a time by Mr. Harry M. Pope was fairly representative of the type. See Figure 42. It consisted of two steel "V" blocks which were bolted to a very firm and heavy bench set in the ground. The rifle barrel, with the forearm removed, was laid in these two V's, which contacted the barrel just in front of the receiver and a few inches in rear of the muzzle. By means of screws the rear block could be moved in elevation and azimuth for the initial sighting of the rifle on the target. The right hand was held in rear of the butt-plate and the trigger was squeezed with the left hand. On discharge, the rifle slid to the rear through the V's, the recoil movement being slowed up by the right hand. A ring clamp around the barrel in rear of the front V position carried a stud on its under side, and on pushing the

barrel forward again into firing position for the next shot, this stud entered a "V" cut on the rear surface of the front block, thus causing the rifle to return to exactly the same position after each shot and making resighting unnecessary.

Such a rest was possible only for a rifle having a heavy barrel of little taper from breech to muzzle, and with a cartridge of fairly light recoil, not much heavier than the .38-55 black powder cartridge. It could not be used with any "one-piece" stock rifle, as the forearm interfered.

Prior to about 1915 the Frankford Arsenal Machine Rest was used almost universally by the Ordnance Department of the Army and to some extent by the various cartridge manufacturers for routine ammunition testing. It consisted of a very heavy steel base bolted to a heavy concrete pier set in the ground to below frost line. A heavy carriage was pivoted at its front end in this base, and was adjustable in elevation and azimuth at its rear end. A heavy steel slide fitted in this carriage with movement back and forth to take care of the recoil of the rifle. The slide carried three posts or clamps to which the rifle could be bolted at muzzle, breech, and butt. Leather washers prevented the clamps from marring the rifle. When the rifle was fired the heavy slide moved slightly to the rear through its runway on the carriage, and was then pushed forward again to a constant position after each shot. See Figure 43. Figures 44 and 45 show the concrete pier, the base, and the adjustable carriage of this rest, but do not show the slide. By slight modification of the clamps almost any rifle could be held in this rest without removing its stock.

It required a great deal of skill and experience on the part of the operator to use this rest with anything approaching reliable results. It was generally considered that it would hardly equal the results obtained by a skilled rifleman firing the rifle from the prone position and using the gunsling as an aid to steady holding. The rifle was under constant strain in this rest, its jump and vibration were restricted, and it did not seem to shoot as accurately as when it was held in the hands. The design of more efficient rests practically eliminated it, or rather its slide, for ballistic experiments and important accuracy tests about 1915, although it is still used for routine ammunition testing.

The Mann "V" Rest. This was designed by the late Dr. Franklin W. Mann, and may be said to be the only machine rest that eliminates all human error. It consists of a heavy block of steel, about 7 inches wide, 5 inches deep, and 40 inches long, with a deep "V" slot accurately machined and polished in its upper surface. For convenience this block is usually held in the carriage of the Frankford Arsenal rest so it can be adjusted in elevation and azimuth. See Figure 44.

The conventional rifle cannot be used in this rest. It must be used in conjunction with a special Mann barrel, bored, rifled, and chambered for the cartridge it is desired to test. This is a very heavy barrel, about 1½ inches in diameter, turned or fitted with two concentric steel rings near the breech and muzzle. It lies in the V on these two rings, as shown in the illustration. The breech action is either a special concentric action, or a normal action with forearm and butt-stock cut off. To use, the rifle is loaded, placed in the forward part of the V, and the trigger is squeezed between thumb and forefinger. The recoil causes the barrel to slide straight to the rear through the V, exactly in the line of fire. If the recoil of the cartridge is sufficient to cause the barrel to slide completely to the rear end of the V block, it is caught and braked by the free hand held a few inches in rear of the action. There is no jump or vibration because the whole barrel and action are practically concentric with the bore, and because all movement is in the line of fire. This rest is now used almost exclusively for experiment and serious accuracy testing in all fully equipped ballistic laboratories.

The Woodworth Cradle. Mr. Al. Woodworth, Ordnance Engineer at Springfield Armory, designed this cradle in which a normal rifle in its stock can be held and fired in the Mann V Block. As arranged for the Springfield 1903 service rifle, this cradle is shown in Figure 45. It consists of two heavy steel blocks, joined together by two heavy bars, rounded on their under surface so they will ride accurately in the Mann V, and channelled on their upper surface so that the rifle will rest securely and accurately in these channels located at the receiver of the rifle, and a little in rear of its muzzle. Heavy clamps, bolted down from above, secure the rifle in these channels, the clamping being on the top of the barrel and the under side of the upper band in front, and on the top of the receiver and under surface of the guard in rear. The rifle is clamped so tightly that it does not move in the cradle. When it is fired the entire cradle with the rifle slides to the rear through the Mann V. An index arm prevents any canting in the V. In addition to the original cradles constructed for the Springfield 1903 rifle, it is understood that others have been made for the Winchester Model 52, and the Remington Model 37, .22 caliber match rifles, and are used for the routine testing of .22 Long Rifle match ammunition. A Woodworth Cradle could probably be made for almost any rifle if the heavy expense were justified, but so far as known it has been made for only the above three models. It has proved very successful for testing an individual rifle for accuracy, or for testing ammunition to determine its performance in a normal rifle. In the hands of a skilled operator who has learned how to clamp the rifle in without strain, it is almost free from error; at least enough so for most practical purposes.

With none of the above machine rests does a rifle shoot to the same center of impact as when held normally in a rifleman's hands. Machine rests are therefore worthless for sighting in a rifle to determine its zeros in elevation and windage for normal shooting. The Woodworth Cradle was used at Springfield Armory for the accuracy testing of every National Match and Sporting rifle for accuracy, and certain service rifles were selected at random from the day's production for accuracy testing in this cradle. In the large commercial plants, rifles are targeted from bench rests by a crew of skilled targeters who adjust the sights until the rifle groups in the bullseye at the prescribed distance, following which a group of five shots is usually fired to prove accuracy before the rifle passes inspection. A commercial rifle thus sighted, is of course sighted only for the particular ammunition used in the testing. This sight adjustment may or may not be correct for the individual who finally purchases the rifle, depending on that individual's eyesight, how he aims the rifle, and with what tension he holds it. But usually it comes fairly close to the finally correct sight adjustment for offhand shooting at the testing distance.

Generally speaking, ordinary .22 caliber commercial rifles are tested and targeted at 50 or 75 feet, and .22 caliber match rifles and high power rifles at 100 yards. But the sights of most high power rifles are adjusted at 100 yards so that the shots group at a distance above the point of aim equal to the 200 yard trajectory, thus the sight adjustment is supposed to be correct for 200 yards.

Bench Rests

Generally speaking a bench rest is the most useful arrangement for accuracy testing, determining elevation and windage zeros, and for ordinary ballistic tests with various rifles and ammunition. The rifle is held and aimed by the shooter whose elbows and body are firmly supported by the bench, the forearm of the rifle being rested at a convenient height on a pad. In this way an extreme steady position can be assumed. Any rifleman can construct a bench rest at little or no cost, and after a little practice with it he can hold so steadily that no movement on the target can be noticed even with a high power telescope sight. A perfect trigger squeeze, however, is always necessary in order that this steady hold be not disturbed at the instant of discharge. A little more practice will enable the shooter to hold so uniformly that there is practically no variation in the tension from day to day. There is error, of course, but it is so small as to be of no practical importance. A rifle zeroed or sighted on a bench rest with good padding under the forearm is practically correctly sighted for use in the offhand, kneeling, and sitting positions for the man who does the shooting.

A bench rest merely consists of a heavy and firm table which is cut away at its left rear corner to admit the shooter's body, and is provided with a padded rest for the forearm which is adjustable for height, and which can be set at a convenient position on top of the table. The bench should be ample in size and steady, the heavier the construction the better it is.

Figure 46 shows the design of such a rest that the writer has used for many years, and it seems to be entirely satisfactory for all rifleman who have fired from it. The legs consist of 4 × 4's, which in the outdoor range are sunk a foot in the ground, and in the winter shooting house are spiked through the floor. The top is of 1¾-inch smooth plank. The height of the table top above the ground should be about 28 inches so that as one sits in a chair or on a stool he can lean over the table and rest his elbows firmly on its top, but this height can be varied afterwards by altering the height of the chair or stool. The dimensions of the top are important, as many make it entirely too small. Minimum dimensions are given on the sketch.

The forearm rest is made in the form of a box that can be weighted with stones or bricks placed inside, and can be moved to any desired location on the table top. It should not be fastened to the table top, as its location thereon frequently has to be varied to suit the particular weapon being tested, the position and size of the shooter, and so that the rifle aims normally on the target when the shooter assumes his steady position. The near side of the box is made high and cut on a slant, with notches which are padded with sponge rubber about half an inch thick. The three notches shown seem to provide sufficient variation in height. The box should not be made until the table has been constructed and is in place on the range, so it can be built of such height that the rifle aims at the target when held in the normal bench rest firing position.

To use the rest the shooter sits on a chair or stool of convenient height at the left rear corner of the bench, and leans slightly forward so that the left and front of his chest is pressed and supported against the cut-out portion of the bench. The forearm rest is pushed to that position on top of the bench so that the center of the forearm of the rifle rests in the padded notch when the firing position is assumed. The arms are folded with the elbows resting down on the bench top. The butt-plate of the rifle rests against the upper right arm close to the shoulder, but not in against the shoulder proper to quite the extent as when shooting in a normal firing position. The left forearm should rest on the bench, and extends to the rear under the butt-stock of the rifle; the first and second fingers grasping in rear of the toe of the butt-plate, and the third and little fingers are wedged between the toe of the stock and the top of the bench. See Figure 47. To aim slightly higher, or lower, a little more

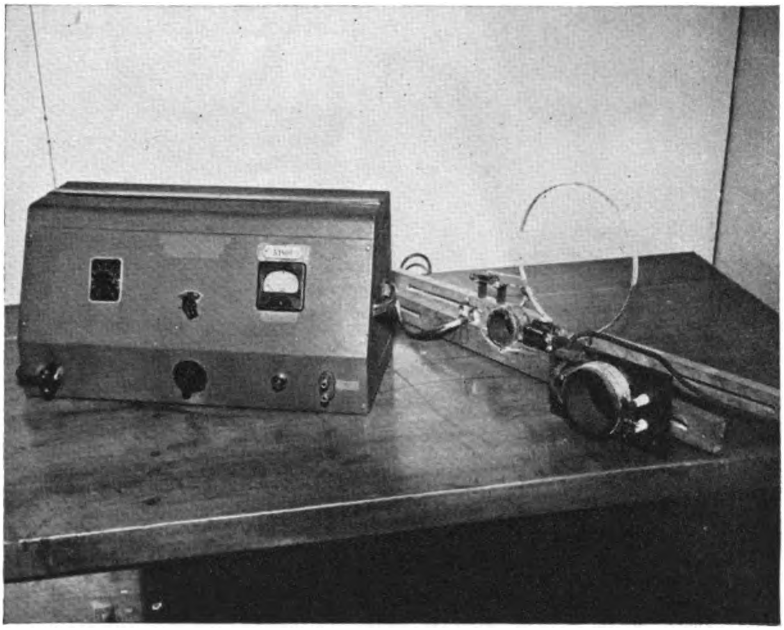
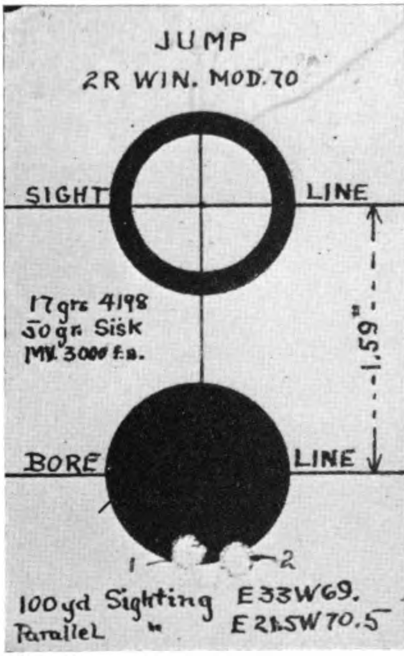


FIGURE 22

The Remington Arms Company Coil Disjunctor Unit is used to provide the start and stop signals for the velocity measuring device in use. The coil disjunctor makes use of the reaction of a radio frequency oscillator to the presence of the metallic projectile in the coil. The presence of the projectile in the coil causes an increase in plate current of the oscillator and this increase in current produces a pulse of voltage across a register in series with the plate supply. The voltage is amplified and made available at the pair of terminals on the lower right side of the panel.

The photo-electric type disjunctor consists simply of a light source and a photo-cell with a suitable amplifying current. This type disjunctor can also be used out-of-doors with no artificial light source, and when so used it is sometimes known by the expression "sky-screen."



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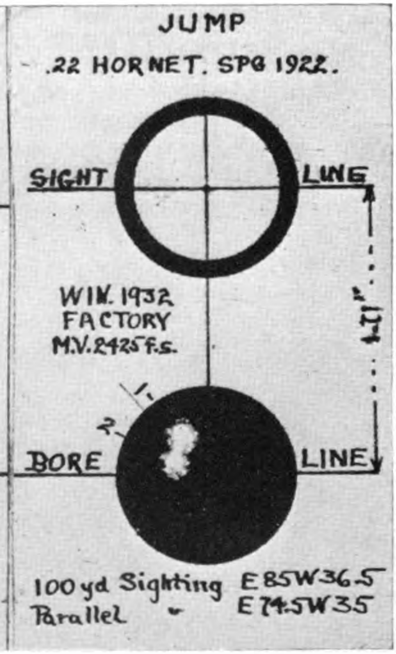

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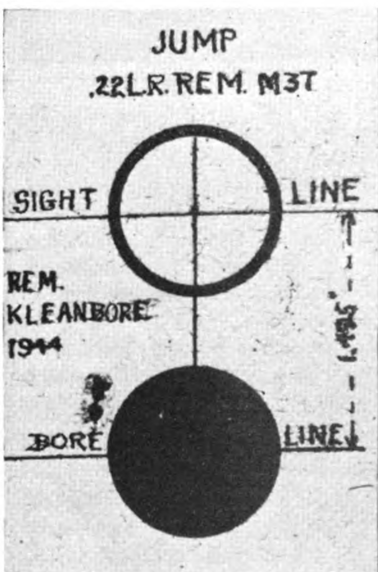

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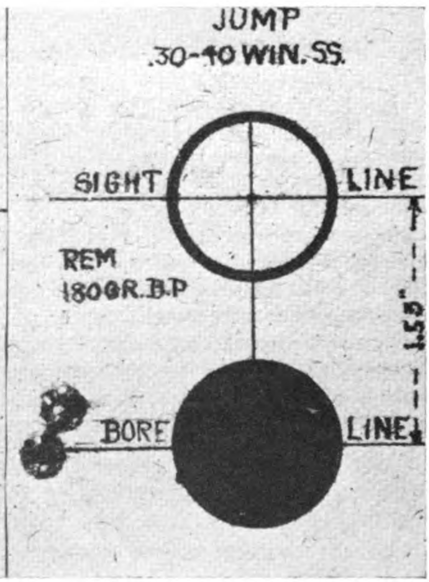
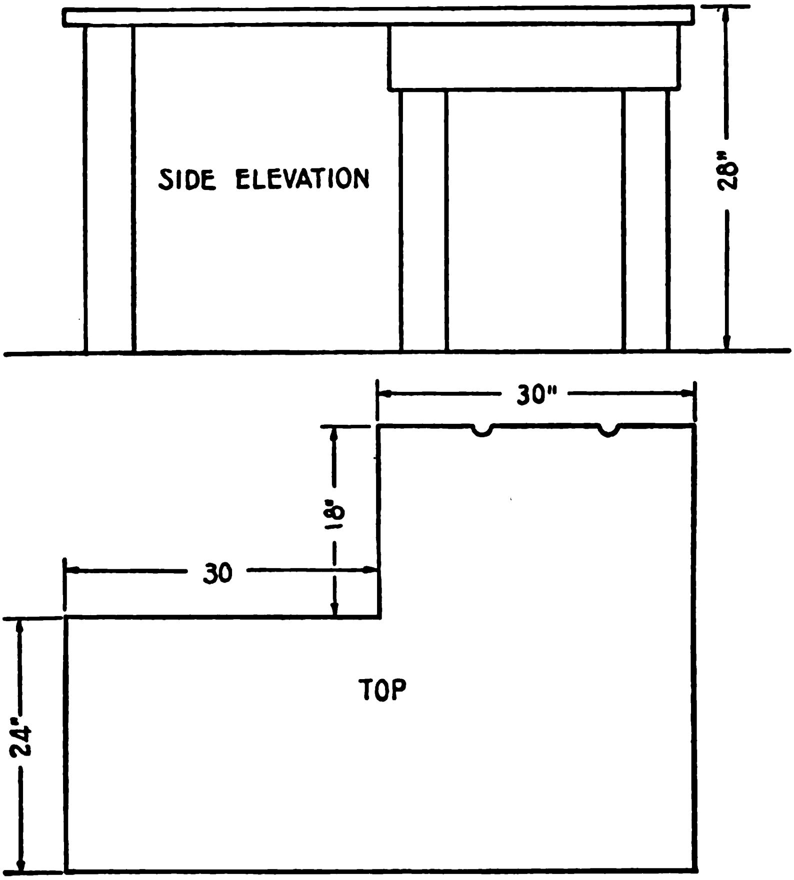


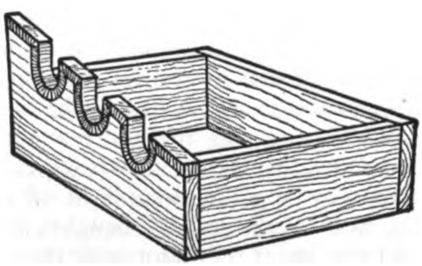
D

FIGURE 23

Determination of Jump. The axis of bore and line of aim were made parallel. The distance between the center of the top aiming circle and the black bullseye is the same as the height of line of aim above axis of bore. Range 12½ yards. The bullet holes show the positive or negative jump.

See page 67 for analysis of groups.





FOREARM REST

Figure 46

or less of these two fingers are wedged under the toe. Sometimes it is necessary to slip a little piece of board, about five inches square, and 1/2 to 2 inches thick between these fingers and the bench top to raise the butt of the rifle sufficiently so that the rifle aims on the target. If the rifle aims too low, use a higher notch on the forearm rest. The right forearm rests on top of the left forearm and wrist so that the right hand grasps the small of the stock, and the right forefinger rests on the trigger conveniently. Changes to the right or left so as to bring the aim on the target are made roughly by pushing the forearm rest to one side or the other, and minutely by pressing harder against the bench edge with the chest, or letting the elbows slide a little out or in on the bench top. When the position has been assumed, aim and squeeze a few shots with an empty rifle so as to see that the position is steady and comfortable. The rifle should aim directly on the bullseye without any muscular strain anywhere. This position is far steadier and more comfortable than attempting to assume a higher position simulating the position one assumes when firing prone on the ground.

If heart pulsations are noticed when aiming they are usually due to shooting too soon after a hearty meal or after exercise. They can usually be minimized by pressing the right side of the chest only, rather lightly against the edge of the bench. The writer has noticed that each spring, when he is relatively a little soft from not having done much shooting in the winter, there is a tendency to heart pulsation, and also to perspiration from the face that clouds shooting spectacles, but these cease after several weeks of strenuous work on the farm in the sun. He thinks that these troubles, in a healthy individual, are due largely to not being in hard physical condition, and not being used to strong sunlight in the open.

It is very convenient to locate the spotting scope and its stand on the bench top to the left of the rifle, and just in front of the shooters left side, where a simple turn of the head allows one to look through the scope and see the location of the shot on the target without disturbing the position of elbows and rifle. Ammunition, recording paper and pencil can be placed on the bench just to the right of the right hand. It will be noticed that several notches have been cut in the left edge of the bench top in which to rest the barrel of a rifle, butt on the ground, while preparing the bench for shooting. This has been a great convenience. In the open it is sometimes desirable to rig up a simple screen to keep direct sunlight off the bench top and sights of the rifle. Both of the writer's benches are arranged so that there is a normal firing point right alongside them where he can at any time fire prone and standing, and thus compare bench with normal shooting. This also has been very convenient.

Many rifleman have constructed portable bench rests, made simi-

lar to the above, but with three folding legs. The portable rest can then be placed in a car, together with a simple target frame, and one can motor out to a convenient pasture, set up the rest and target and go to shooting with little delay or inconvenience. But a big, steady bench is always better. One friend of the writer's made one entirely of concrete so he could go away and leave it unguarded without any danger of its being injured by vandals.

Bench Rest Shooting. For any rifleman bench rest shooting is extremely useful and interesting. At the bench he can determine the capabilities and characteristics of his rifle, and of any and all loads that are suitable for it, and he can do all this with such surety and absence of error that he can place reliance on his findings. But for the amateur ballistician and the experimenter the bench rest is an absolute necessity. Its great advantages are that it is adaptable to any type or model of small arm, and that anyone can learn to use it in a few days with practically no error. The machine rest and the Mann "V" rest require a very considerable investment with a machine shop in the background.

Moreover, bench rest shooting is the most interesting and comfortable form of rifle shooting. One sits comfortably in a chair, there is no awkward position or physical effort, no dirt to lie in, and ordinary clothes may be worn. Because it gives the answer to the problem right away, it is the most satisfactory and interesting form of shooting for those who care for the rifle because of its mechanical and scientific aspect The competition is with records, systems, materials, inventions, gadgets, etc. The most interesting and profitable hours that the writer has spent with his rifles have been those at the bench rest—more interesting even than rifle matches in good company.

Bench rest shooting does take skill, but it is a skill that is easily acquired. Anyone who has shot just a little with the rifle, who appreciates the necessity for careful aim, steady hold, and a good squeeze, will shoot well the very first day provided he will pay attention to small details and use his brain, and *concentrate*. It does require intense concentration. The shooter must put his whole thought and effort on aim, hold, and squeeze if he would get his shots off without error. He lays out his program so that nothing is omitted or forgotten, and so that no chance for an error can creep in. The position must be absolutely uniform each shot, and above all each shot must go off *unexpectedly*.

It is practically impossible for anyone to concentrate to the extent necessary for errorless and reliable work with a companion or spectators present. Bench rest shooting is a lone game. An audience will always distract one so that errors are made. Even the presence of a "sympathetic soul" is detrimental. There should be no one to shake

or shade the rest. There should be no one to ask a question, make a comment or a noise that will distract attention from doing everything exactly the same each time, or from evaluating correctly everything that is done or that occurs, or from setting down the proper record at the proper time. There should be no one to make him hurry, nor should he have an engagement which requires him to complete his work at a specified time.

Bench rest shooting in the steady position shown in Figure 47 is limited to rifles of light or medium recoil; generally speaking to a weapon recoiling not more than does a .30-06 rifle of eight pounds weight with full charges. With heavier recoil the barrel jumps up from the forearm rest excessively, and the recoil is usually so disturbing and uncomfortable that one cannot endure many shots before the concentration necessary for errorless aim and squeeze becomes difficult. Even with an eight pound .30-06 rifle few men can concentrate sufficiently for errorless shooting for more than about twenty shots in a morning or afternoon.

With rifles of heavy recoil the position at the bench rest must be different. Substitute a thick sandbag for the notched forearm rest. Assume a position with elbows on top of the bench, elbows placed on the bench about as one would place them on the ground in firing prone, rifle held higher above the bench top. Grasp the forearm as in the prone position, and rest the back of the left hand on top of the sandbag. This position is not absolutely steady, being about as steady as the normal prone position with the gunsling. But the rifle does not jump up so much, and the shoulder and body give backward with the recoil which is not felt to a disagreeable degree. This is the best position in which to test and target a rifle of heavy recoil. Shooting in this way the writer has been able to conduct accuracy tests, and sights in heavy elephant rifles with no difficulty whatever. These extremely heavily charged English elephant rifles, .450 to .577 Cordite, cannot usually be fired more than ten rounds or so at one time, not because of the pain or bruising of recoil, but rather because of the shock to the entire nervous system. Continued firing might render the shooter unconscious much as repeated heavy, but not painful blows, often put a pugilist out for the count.

The program is laid out several days, or perhaps months in advance. Every detail is prepared in advance. Ammunition is loaded ahead of time. The necessary tools and equipment are at hand. Often there has to be a delay for suitable weather, for a day with no wind, with a strong wind, a cold or a warm day, a dark or a bright day, according to the problem that is to be solved. Then comes the day of realization, a few most interesting and absorbing hours. One has developed a load that has broken all records, he has determined a trajectory that he always wondered about, he has made the small-

est group he ever made, he has found just how cold weather or fouling or fast shooting affects his rifle and ammunition, he has determined exactly how much wind deflects the bullet, or how light affects the aim, or alas some pet idea has proved worthless. Perhaps what John Jones told him proves to be absolute bunk. The writer thinks that bench rest shooting is likely to increase greatly in popularity in the post-war years that are to come, and with its aid our riflemen are going to become even more skillful.

Bench Rest Shooting for Beginners. The best way, the quickest and easiest way to teach a beginner to shoot the rifle is to start him off at the bench rest. As the Army Manual states, the whole soul of good rifle shooting lies in the trigger squeeze. But one cannot even begin to learn trigger squeeze until he has learned to hold the rifle steady, and that is the hardest thing of all to learn—unless one uses a bench rest.

In squeezing, or "pressing" as the writer prefers to call it, we are taught that we must apply the pressure on the trigger very gradually, ounce by ounce, while still keeping up our effort to aim accurately and hold steadily. But we must apply and increase the pressure only when the sights are correctly alined on the bullseye. During those periods when the sights drift off the bullseye we must stop our increase of pressure on the trigger, and merely hold the pressure that we have already applied. We must go on with the gradual increase of pressure only when the aim is perfect. It follows then that sometime during this increase the rifle is going to be discharged unexpectedly. Because the aim was correct at that instant, the bullseye will be struck. Because the discharge came unexpectedly we will not have instinctly set our muscles against the coming report and recoil, will not have flinched or jerked the trigger.

All this is correct. But how on earth is a beginner to do it? He cannot hold the rifle steady, the sights are bobbing and trembling all over the target. He does not see the sights alined on the bullseye for even a quarter of a second at a time. It is impossible for him to increase the pressure on the trigger when the aim is correct for there is no such time. The beginner is so confused that progress is impossible.

The usual successful method is to first teach the beginner to assume and to hold steadily in the prone position with the gunsling, and when steadiness has been acquired in this position, to teach him the trigger squeeze as he holds the rifle steady in that position. But the trouble is that to acquire steadiness in the prone position requires about a week of practice, much of it under the expert guidance of a competent coach. The position must be assumed correctly, there must be several periods of fifteen minutes practice

daily to get accustomed to an unfamiliar position, and to become comfortable and steady in it. A week of such work is necessary to get over stiffness, to learn always to assume the position correctly, to become comfortable and steady. But the beginner always wants action at once. He rebels at a whole lot of preliminary exercises. *Particularly he wants to shoot the very first day. We can safely allow him to shoot the first day only from the bench rest.*

The beginner must first be taught to aim correctly. This is the easiest thing of all to teach. Five minutes of explanation followed by ten minutes with the aiming bar will do it.

Then we take our youngester to the bench rest and put him in the correct position at it. He at once finds that he can aim steadily on the bullseye, and hold his aim on it for five minutes if necessary, with no effort or strain at all. *Then* we can start him on the trigger squeeze as above, at first with an empty rifle, but in ten minutes we can profitably begin to insert cartridges. Then he sees results, he is hitting the target, he is hitting in the bullseye, he is shooting and getting a good score. His interest is intense, and that interest is going to last, and to increase day after day, until he has become a finished marksman.

The writer has used this method exclusively for the past five years. In fact where the beginner has ordinary intelligence he does not even bother to use the aiming bar. He simply gives him a little beginner's manual where he can read about aim and trigger squeeze, and then he takes him to the bench rest. The first ten shots that these beginners have pressed on their first day have never resulted in a score of less than 85 at 100 yards on the N. R. A. target. Two beginners made 97's for their first ten shots. First class equipment should be used. The instructor wants to see his pupils' errors stand out alone, and not to be hidden in a whole lot of errors and inaccuracies of rifle and ammunition.

Immediately after shooting at the bench the beginner is made to lie down at the firing point and is instructed in the prone position with the gunsling, aiming at the same target that he shot at from the bench rest. But he does no shooting for the first few days in this prone position—not until he has acquired real steadiness and comfort in it. His interest is kept up by letting him shoot at the bench, encouraging him to make high scores and small groups, and by manipulation of the sights, to place a small group just five inches above the bull, and another just five minutes to the right. Within two or three days at the bench proper trigger squeeze has begun to be a fixed habit. That is the important thing you have been working up to; to impress upon the shooter that when the rifle goes off unexpectedly he is going to get a ten. When he has learned this, by that time he is also probably steady and comfor-

table in the prone position, and then you can safely allow him to start shooting prone, supervising him at first so that he realizes he has to squeeze the trigger properly in that position as well to get results, and that results depend only on his squeeze. Almost always the second score prone will be at least an 85. He has had a week of shooting that has been most *interesting* to him, he has learned a lot of *interesting* things, and he is now making really good scores. Just a little more practice prone, then we show him the sitting position, then the kneeling, and finally the standing. The period of intense coaching is over. We can now allow him to work out his own solution, and his problems, and he will do it every time, only coming to his coach once in a while for a little advice. In three weeks from the start he is a pretty darn good shot. This system is much easier on the man and on his coach. There is less danger of the beginners learning bad habits that may delay progress. It is based on rising the interest to an intense pitch at the start and keeping it there.

Back again to the trigger squeeze; the whole soul of good shooting. We have described it above; this description when carefully analyzed is correct. That is the correct way to describe it to the beginner at the start. But we find that in a day or two we can profitably tell him the story a little differently, and about as follows:

He assumes the correct firing position. He takes a deep breath, then he allows his lungs to become normal, and he holds his breath when he starts to aim. At the very start of the aim he places considerable pressure on the trigger, enough by past experience so that only an ounce or two more would discharge the rifle. All this he does almost without thinking about it. It is routine. We call it "Taking command of the rifle." He now concentrates his whole effort and thought on steady hold, and accurate aim, and he coordinates these with a gradual increase in the last couple of ounces of trigger pressure. He is now at the critical point. Suddenly, *unexpectedly,* his rifle is discharged. By "unexpectedly" we mean that the good shot does not know within a quarter or a half a second of when his rifle is going to discharge. Then he will get a bullseye. That is the way you and I squeeze our triggers in slow fire.

In slow fire the time from taking command of the rifle until the rifle goes off unexpectedly should vary from about two to eight seconds. This is the time of great concentration. This applies to shooting prone, sitting, kneeling, or at the bench rest. Over ten seconds is too much time. One cannot concentrate properly for so long a period. Better let up and start all over. With such a concentration and such a squeeze, if one is using a telescope sight (so the aim will be practically errorless), there should be practically no human error in bench rest shooting, and only the error of rifle and

ammunition should result. We speak of holding absolutely steady in the prone position. This is only relative. It may look absolutely steady if we are using iron sights, but with a high power telescope sight we will see that a slight tremor is always present.

We are not describing slow fire, offhand shooting here. That is an art that it properly described in works on marksmanship.

In rapid fire shooting the whole procedure is merely an acceleration, not a change. There is no time for absolute perfection of aim and squeeze. Nevertheless the habit of correct trigger squeeze should continue and persist. One is content with not quite perfection when he squeezes on the last ounce. He thinks he knows when the rifle is going off. Perhaps he does, and perhaps he does not. He finds, however, that if he continues to indulge in careful slow fire daily after he takes up rapid fire, that after a little practice at rapid fire he is doing everything rapidly pretty much as he did it slowly, and he is doing pretty darn well at that. In rapid fire he is not getting all his shots in the ten ring by any means, but if he is shooting at 100 yards he is getting all of them in the 8 ring, and most of them in the 9 or 10 rings. He is putting five shots in twenty seconds in a six inch bullseye at 100 yards. His scores are now running 98 to 100 slow fire, 85 to 90 rapid fire. He is a rifleman, provided he will end up by a little practice at swinging on moving targets.

Such shooting demands a fine rifle and ammunition, a knowledge of their performance, of sight adjustment and wind allowance, and other things. The way to find out if all this equipment, and this information is up to the mark, to bring them up, and to keep them there, is in bench rest shooting.

Target Measurements

The common method of measuring a group of shots fired on a target, to give it a value, and to indicate the degree of accuracy, is to measure the distance between the centers of the two bullet holes farthest apart. Such a measurement is termed the "extreme spread." To make this measurement with a desirable degree of accuracy, place the target over a sheet of paper and, with a sharp stylus, prick the paper in the centers of the two bullet holes, centering the two holes as accurately as possible. Usually the eye will center the holes within 1/50th inch of exact center, which is close enough. Then remove the target and measure the distance between the two prick marks on the paper with an engineer's scale graduated in tenths and fiftieths of an inch. See Figure 48A. The extreme spread will usually be the diameter of the circle which contains all bullet holes, but not invariably. Figure 48B shows a case where the extreme spread does not indicate the diameter of the inclosing circle.

In competitive ammunition tests, the Ordnance Department of the Army uses the "Mean Radius" method of measurement. The mean radius is the mean of the distances of all the shots from the center of the group. To determine it place a square on the target and rule a horizontal line through the center of the lowest bullet hole, and a vertical hole through the center of the left bullet hole.

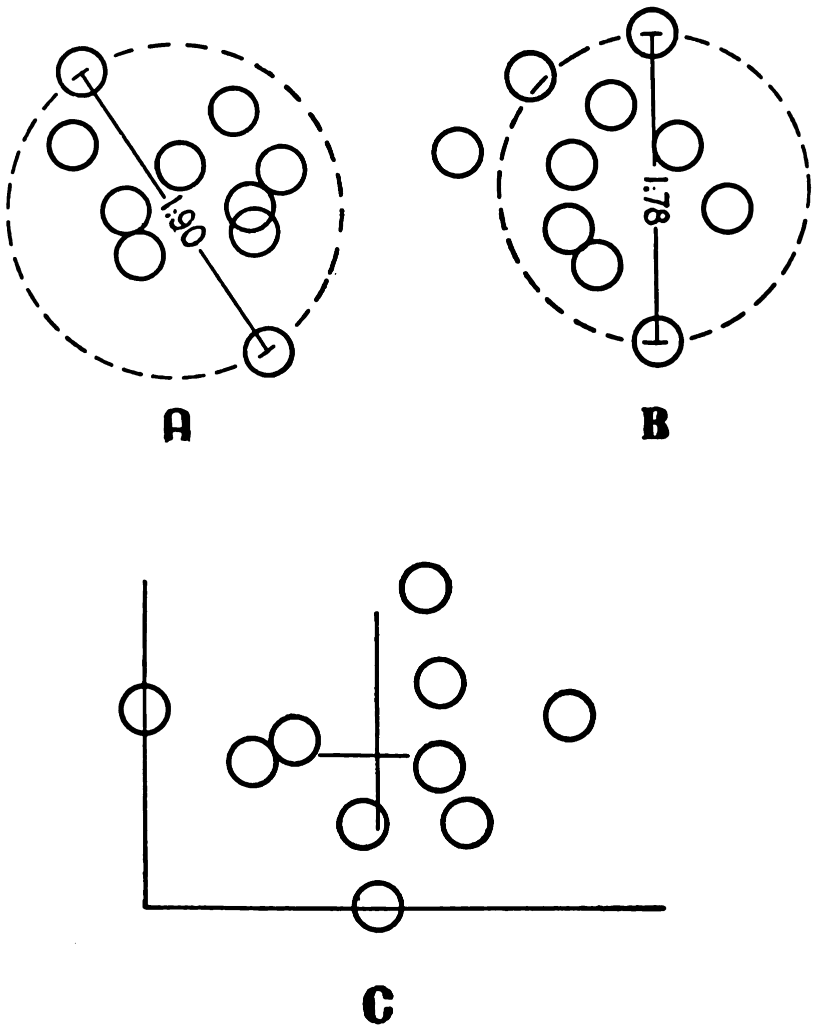


FIGURE 48

A—Extreme Spread. B—Extreme spread does not always indicate the diameter of the circle that will include all bullet holes. C—Measurement of Mean Radius. The cross is the center of the group, or center of impact.

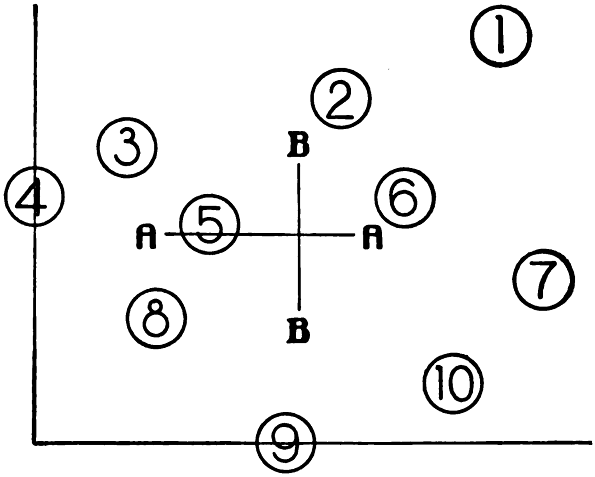


FIGURE 49

To determine the Mean Radius we first find the center of the group.

Place a square on the target and draw a horizontal line through the center of the bottom shot hole of the group, and a vertical line through the center of the left shot hole of the group. Then measure the vertical distance from the horizontal line to the center of each bullet hole, add these measurements and divide by the number of shots in the group. At this distance above the horizontal line draw a second horizontal line A—A. Similarly measure the horizontal distance from the left hand vertical line to the center of each bullet hole, add these measurements, and divide by the number of shots in the group. At this distance to the right of the left hand vertical line, draw another vertical line B—B. Where lines A—A and B—B cross will be the center of the group.

From the center of the group measure the distance to the center of each bullet hole, add these distances, divide by the number of the shots in the group, and the result will be the Mean Radius of the group.

The following is the calculation for the above group:

Shot No.	*Vert. Dev.*	*Horiz. Dev.*	*Radii*
1	2.10 *	2.48	1.45
2	1.78	1.59	.75
3	1.53	.47	1.00
4	1.27	0.00	1.38
5	1.12	.91	.45
6	1.25	1.88	.59
7	.85	2.62 †	1.30
8	.69	.63	.85
9	0.00	1.04	1.09
10	.30	2.17	1.12
	1.089	1.373	.998 Mean Radius

* Extreme vertical deviation 2.10″. † Extreme horizontal deviation 2.62″. Extreme spread (shots 4 to 7) 2.68″.

See Figure 48C. Measure the vertical distance of the nine shots above the horizontal line (assuming it is a 10-shot group), and divide the sum of these measurements by ten. At this distance above the first horizontal line draw a second short horizontal line. Similarly measure the horizontal distance of each of the nine centers of bullet holes from the left vertical line, divide their sum by ten, and at that distance to the right of the first vertical line rule a second short vertical line. Where these two second short horizontal and vertical lines cross will be the center of the group. Now measure the straight line distance from the centers of each of the ten bullet holes to the center of the group, add these measurements and divide by ten, and the result will be the mean radius. The mean radius is the true value of the target as it indicates the average distance that each shot deviated from the center. But it is rather difficult to visualize the size of a group from its mean radius, therefore it would be well to also add the extreme spread to the record.

Sometimes it is also desirable to give the extreme vertical spread and the extreme horizontal spread; that is the height and width of the group. With a good rifle and ammunition, on a calm day, the extreme verticals and horizontals of a number of targets should be about equal; that is a composite group should be more or less round. On a windy day the horizontal spread will usually considerably exceed the vertical spread. When the vertical spread is large it rather indicates a variation in velocity, either from varying powder charges or varying ignition or bullet pull.

Accuracy

One of the major problems of the ballistician will be to obtain accuracy with the small arms and ammunition that he handles. And one of the chief uses of a rifle range is to so regulate the rifle, and so prepare the ammunition as to obtain the finest accuracy. To obtain fine accuracy two things are necessary—proper design and uniformity. Accuracy is but another word for uniformity. But these two things cover a multitude of sins. In fact, every page of the two volumes of this work has dealt with them more or less, and hence the present discussion must be in the nature of a repetition or recapitulation.

We imagine that the average shooter, who has not given much mature thought to the subject, would define accuracy in a rifle or pistol, and their ammunition, as those qualities which will result in consecutively fired bullets striking within a small group. But the writer would go a little further than that. What is a rifle for but to hit small objects at a distance? The smaller the object and the greater the distance at which it can be struck, the greater the accuracy. Not only must the rifle and its ammunition make a small

group, but the shooter must be able to center this group on the object with certainty today, tomorrow, or a year hence. In other words accuracy involves being able to hit a small object at a distance without sighting shots. The weapon and ammunition must maintain their zero. Then only poor marksmanship, inability to estimate distance correctly, or wind will result in a miss.

Accuracy is limited at the start by the accuracy of aim. We have already seen that the human eye has its limitations, and that with iron sights there are small errors of alinement which add to the errors of rifle and ammunition. The smallest error of aim results when we use a telescope sight of high magnifying power with a fine reticule.

It is conceivable that we could have a rifle built with such a heavy barrel that the stock and many other details would have practically no effect on its accuracy, jump, and vibration and it would shoot to the same center of impact indefinitely. Then, so far as that gun was concerned, accuracy would depend only on the details of bore, chamber, tight breeching, and firing mechanism, and of course the ammunition.

But so long as we fight and hunt, and limit our rifles to a handy weight, our barrel and breech performance will be more or less influenced by the stock, and to date we have obtained the best accuracy and maintenance of zero with an action having the Mauser type of breech locking, a tightly bedded one piece stock, and a full floating barrel. With such, the accuracy seems to be in direct proportion to the weight of the barrel. So much for the gun's part in the accuracy, that being half of our problem.

The other half is the ammunition. Do the cartridge and bullet fit the bore correctly? If so, then our problem seems to be to select a bullet that is a perfect gyrostat, and to get it through the bore and launched into the air without deforming it. And to launch successive perfect bullets at a uniform velocity.

Perhaps we could define what qualities and characteristics a bullet should have to be a perfect gyrostat, but it would be another matter to make a lot of bullets with such perfection. And yet, if made, they might or might not shoot with fine accuracy, why we do not know. The writer once tried this. On the lines of a lot of fine ammunition that had always given splendid accuracy, he had fifty bullets made as perfectly as scientists and toolmakers in a large ballistic laboratory could produce them. They were loaded with extreme care, in uniform cases, with weighed charges. The results were just uninteresting. There seems to be something intangible about a good bullet. Is it hardness of jacket, is it shape of base or point, is it sectional density or location of center of density, is it the relationship of all these to one another? We do not know. We

only know that from certain bullets we usually get super-fine accuracy, notably:

The .22 caliber Wotkyns-Morse 8S bullet.
The .25 caliber 117 grain Western soft point, boat tail bullet.
The .270 caliber 150 grain Western soft point bullet.
The .30 caliber 172 grain Western Tool and Copper Works open point bullet.
The .30 caliber 180 grain Palma Match bullet.
The .30 caliber 172 grain Frankford pointed, boat tail bullet, selected.

There may be others, the writer is not sure, but at least these pre-war bullets have given a superior order of accuracy, although some manufactured lots have been better than others. Note that all six have very different forms and construction, so we learn nothing in that respect. These bullets are now all gone with the wind. What will be the most accurate bullet in post-war manufacture, and who will make it? Of course we do not know. Apparently there is going to be a lot of chance for experimental work after the war.

Having found an accurate bullet we can determine by experiment what primer and powder and what weight of charge will give the best results. Probably we are safe in saying that the charge that gives the best accuracy is the one that sends the bullet through the bore with the least deformity, and that delivers it with the most uniform velocity. Powder charges should be weighed to within 1/10 grain. It is well also to weigh each bullet, for in certain lots we may find a variation as great as two grains, although bullets that show fine accuracy are usually very uniform in weight.

The cartridge case also requires careful attention. It is well to select by weight, for we sometimes find considerable variation. As cases are expanded by firing and are then sized to a uniform outside diameter and shape, any variation in weight means a variation in capacity and hence density of loading. It would seem to be hardly worth while to weigh our powder charges if our cases so lack uniformity as to give us considerable variation in density of loading. But more important still is the bullet pull. Variations in the tension with which the bullet is held in the case neck will always be reflected in the size of the group because such variations give us variations in velocity. The writer has also noticed that sometimes the make of the case has an influence on accuracy. Identical loads sometimes give different accuracy and also different location of center of impact with different makes of case. In one instance two makes of case gave centers of impact that were 1½ minutes apart horizontally.

In striving for the very finest accuracy it would be well to give attention to every one of these details. Possibly no one would make

any appreciable difference, but the algebraic sum of all may be very material.

Temperature should not be overlooked, particularly in cold weather. In winter shooting, the writer does not attempt a serious accuracy test with rifles and ammunition that have been transported a considerable distance to the range in a cold automobile. They are permitted to warm up for an hour in the heated shooting house before making a test, and several warming shots are fired before starting a record group. That this makes a difference can usually be proved by shooting a group where these precautions have not been observed. Experiments to prove that such things do really make a difference should always be undertaken, as we learn much thereby. A difference in temperature of twenty to thirty degrees in rifle or ammunition, or both, will almost always give a difference in center of impact, although it is sometimes so slight as to make no practical difference unless we are striving for perfection.

Of course to attain fine accuracy marksmanship must be of a very fine order. It takes considerable experience, practice, and study to be able to pull ten consecutive shots, even from a bench rest, without any error in marksmanship.

The First Shot. In hunting and in war the most important shot is usually the first shot of the day. In hunting, the game will usually be standing, and is likely to be unaware of the hunter until the first shot is fired. After the first shot the animal will either be running, or will have disappeared if the first shot does not bring it down. We have already seen that an animal is much more susceptible to shock, and hence easier killed if it receives the first bullet before it is aware of the presence of the hunter.

This also holds true in war. After the first shot the enemy either takes cover, or is firing back.

For this first shot the bore of the rifle is either clean and cold, clean and oily, or cold and fouled. *Under these conditions will the first shot strike where the rifle is aimed?*

In 1902 there was quite a lively discussion among riflemen as to whether the bore of the rifle should be clean and slightly oily, or clean and dry for the first shot of the day. The writer determined to find out, and for this first shot he began to keep a record of the condition of the bore and, of course, of how the sights were adjusted, and where this first shot struck the target. And he has kept that record ever since—for forty three years. He has learned some very interesting things, which in general can be summed up as follows:

As a result of early firing, conclusion was soon reached that it was best to start the day's firing with the bore of the rifle dry, that is with the film of oil or grease that had been in it over night, wiped

out. When the bore had a light coating of oil or thin grease in it for the first shot, and that first shot was fired with the normal sight adjustment, the bullet usually struck the target outside of the group made by succeeding shots. Often it was considerably out of the group. Usually, but not invariably, there was a tendency for it to strike high, above the succeeding group. Occasionally, particularly with big bore rifles, there did not seem to be much difference. But as a rule the first shot was much more likely to be well within the group of succeeding shots if the bore was dry for the first shot; that is dry and cold.

This was particularly true of rifles for the .22 Long Rifle cartridge, and indeed of all small bore rifles firing lubricated lead bullets. The first shot from a cold, oily bore was almost invariably wild, and indeed so was the first shot from a clean, dry bore, but not to the same extent. In hardly any case did the rifle begin to shoot uniformly until three or four shots had been fired through it to foul and warm the barrel. This is well known now and the conditions of all small bore slow fire matches permit five minutes of fouling and warming shooting before starting the record score.

When the Ordnance Department of the Army purchases .22 Long Rifle ammunition from the commercial cartridge companies it always requires that the ammunition come up to a certain established standard for accuracy, and each lot is tested for accuracy by firing a series of ten groups at 100 yards from each of four test rifles. The rifles are held and fired from the Woodworth cradle rest. Each rifle is sighted in on the rest, and then enough shots are fired to show that the rifle is correctly bedded in the cradle, and then ten consecutive groups of ten shots each are fired on one sheet of target paper, the rest being traversed slightly between groups. In the three years during which the writer supervised this testing, in no case was the first group fired the smallest group of the ten. Usually it was one of the largest groups, showing quite conclusively that this cartridge shot at its best when the bore was well warmed, in fact quite hot.

On the other hand the writer's score books, very carefully kept over seven different years of very extensive shooting in the Army and as a member of a number of Army Infantry Rifle Teams, do not show any particular tendency for the first shot fired from clean and cold rifles (.30-40 Krag and .30-06 Springfield) to strike other than well in the group of succeeding shots. The same may be said for the great majority of other high power rifles of .25 caliber and larger. Particularly in those calibers with which the writer has done the most careful shooting, .250-3000 Savage, .257 Roberts, .270 Winchester, 7 mm Mauser, .30-06, .35 Whelen, .35 Remington, and .400 Whelen, all fired for accuracy with the same sight adjustment, the first

shot from a clean, cold bore would almost invariably be found well within the group made by the succeeding shots, with no particular tendency for this shot to strike either high or low.

The .22 caliber high intensity rifles that the writer has tested extensively show considerable variation in this respect. The majority of these rifles are fitted with barrels having a groove diameter of from .2220 to .2228-inch, or else a groove diameter from .2235 to .2240-inch. Some jacketed bullets measure .223-inch, and some .224-inch in diameter. Usually, but not always, if cartridges loaded with .224-inch bullets are shot from a barrel measuring between .2220 and .2228-inch, the first shot from a clean cold bore will strike high above the succeeding shots. In three instances the bullets would be found from 6 to 12 inches higher than the other shots at 100 yards.

Invariably one rifle for the .22 Hornet cartridge, groove diameter .2220-inch, when shot with .2235-inch bullets, and one rifle for the .22-3000 Lovell R2 cartridge, groove diameter .2235-inch, when shot with .224-inch bullets, threw the first shot from a clean cold bore from one-half to two inches higher than the center of the succeeding group of nine shots, but otherwise were very accurate weapons. When starting shooting these two rifles with the bore cold and fouled by previous shooting, there was no tendency for the first shot to be out of the group of succeeding shots.

One large arms manufacturer informed the writer that the tendency for a rifle to throw its first, or first two or three shots from a cold bore rather wild was well known, and that for that reason his firm made no attempt to test rifles for accuracy until they had been fouled and warmed by several shots.

Seemingly very little investigation has been made of this important matter. The writer's tests, although long continued, are too crude to be positive. They were all made when shooting prone with the gunsling or from a bench rest. Always there is the thought that the shooter may not be steadied down for this first shot as well as for the second and remaining shots, and he may not pull it the same. The importance of the matter warrants more careful tests from Mann barrels in a Mann V rest where no human error will be present. It does seem to the writer that oversize bullets seem to increase the tendency of the first shot to fly wild. But the cause should be found, and a remedy applied if possible. For serious hunting and warfare the writer would have little use for a rifle if he could not depend on the first shot striking where he aimed it.

Records

Any work of a technical nature that is worth doing is worth recording. Even if it is only for one's personal future reference the

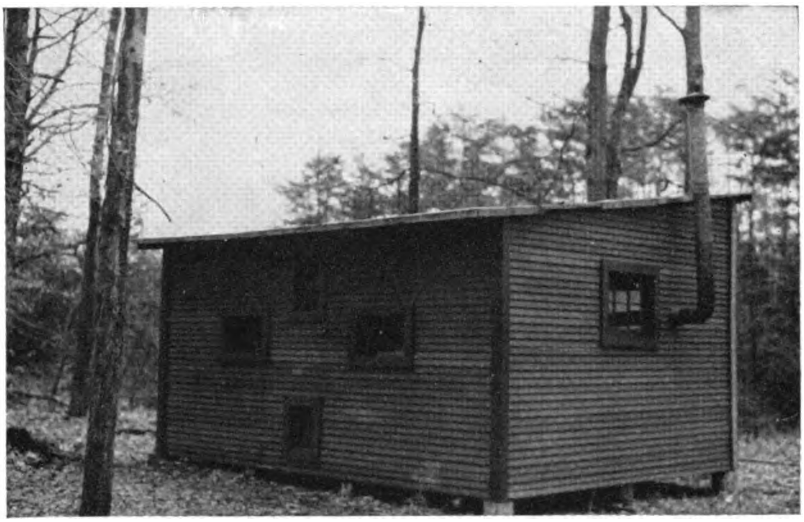


FIGURE 40

The shooting house on the author's winter range incloses two bench rests with space for firing standing and prone, and includes a stove for heating. The four firing ports are shown.

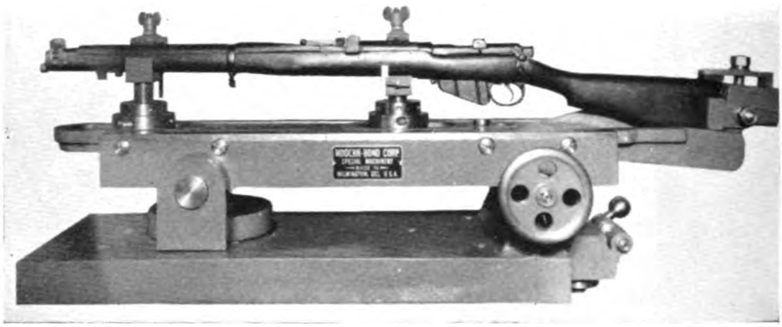


FIGURE 43

The Frankford Arsenal type of Machine Rest as manufactured by the Modern-Bond Corporation and supplied to plants manufacturing ammunition for use in World War II. At the bottom is seen the heavy base which is bolted to a concrete base. Above is the movable base, pivoted at the front, and movable in elevation and azimuth by means of the wheel headed screws seen at the rear. The slide, also shown in Figure 9D, fits in the track on the top surface of this movable base, and carries the three posts to which the rifle is clamped. When the rifle is fired the slide recoils to the rear along the track in the movable base. The rifle shown is the Caliber .303 Short Model Lee Enfield (S.M.L.E.), but the slide will also hold the U.S. Rifle, Caliber .30, M 1903 (Springfield) or many other bolt action rifles.

data should be kept carefully and accurately, for in small arms and ballistic work there are entirely too many important details to trust to memory. The experimenter may also desire, at a future date, to publish some of his data, and will need accurately kept records for that purpose.

For many years all successful and careful riflemen have been in the habit of keeping the record of each rifle they have shot in what is termed a "Score Book." Many different score books for this purpose have been published from time to time, and there is an official one for use in the Army. There should be a separate book for each rifle. The score book is not, as its name would imply, merely a book in which to keep one's scores. Rather it is intended for the keeping of a complete ballistic record of the rifle and of the shooter's performance with it. The pages are ruled and spaced for the essential data, and there is a target diagram on which each shot can be plotted, so it shows the conditions under which each shot was fired, and just where it struck the target.

On the first page there should be recorded the name, number, and caliber of the rifle or other arm, and a complete description of it, as well as the name and address of the shooter, or as they say in the Army—name, rank, organization, station, and "previous condition of servitude." Each of the following printed and ruled pages are designed for recording a score or a series of shots that are fired in practice. In a score book intended for use with a military rifle there are separate pages for recording shooting at 200 and 300 yards slow fire; 500 and 600 yards slow fire, 800 and 1,000 yards slow fire, and for 200, 300, and 500 yards rapid fire, each having also a diagram of the proper target on which to plot the successive shots. Small bore score books usually contain but one type of page for all distances, slow fire, including a diagram of the Official N. R. A. Small Bore Target.

Individual opinion and taste will differ, but it is the author's considered opinion that for a complete and useful record there should be recorded on each of these pages the following explicit data.

Date, distance, sights, and firing position.

The ammunition used, in detail.

Elevation and windage adjustment used, and sometimes for each shot.

Wind velocity and direction. Light. Temperature.

A plotting showing where each shot struck the target.

The score or the extreme spread of the group.

The rifleman takes this score book to the range with him. Some of the above data he records before he starts to fire. He places the score book alongside him at the firing point, and as each shot is signalled by the marker he accurately plots its location on the

diagram. He also records any change in elevation, windage, or wind opposite the shot where it occurred. The record is then completed as soon as he has left the firing point.

This page then becomes a complete record of the performance of rifle, ammunition, and shooter at that time. Any day thereafter, when shooting at the same distance, he can refer to this page, and he will know precisely how to set his sights. When a number of scores have been recorded at various distances and under different conditions, he knows just how to set his sights for any distance, position, ammunition, and for any light or wind conditions. This is the best kind of a record for a shooter using only one, or perhaps two or three rifles, and participating mainly in qualification and competitive shooting and in practice incident thereto. But it is not quite the kind of a record an amateur ballistician, shooting many different arms and ammunitions, and conducting different experiments, will find meeting his requirements.

For many years the writer kept such records, a score book for each rifle, and note and scrap books. Then in 1920 he started a carefully thought out system which he has used to the present day, not finding anything better or necessary. It was thought that records should not only be complete and accurate, but they should be easy to find and refer to, and they should be kept in such form that they could be easily understood by any rifleman or ballistician as they might be of some value to posterity. Unfortunately we have no technical record of any shooting done by old time riflemen. Many scores have been recorded, actual groups have even been retained, but for all this there is almost no exact record of the technical conditions of the shooting.

The records for each rifle, pistol, or shotgun, and for each score, series of shots, or experiment, are kept on cards, 5 x 8 inches in size, which are filed in a card index according to the caliber and make of arm. The cards for each particular arm are kept together in the index drawer and are numbered consecutively. The cards for any one weapon thus form a complete "score book" for that weapon. The blank card can be taken to the range, made out there, and afterwards filed.

At first the cards were printed so as to provide spaces and columns for recording almost every conceivable form of data, quite similar to the more elaborate score books. But it was found that many of these spaces were never used, and that often one wished to record information for which there was no appropriate space or column. Therefore the card was revised so as to provide spaces for only absolutely essential data which always had to be recorded, and space was left for remarks in which anything desirable could be set down. Remarks could also be extended on to the back of the

card. Because the writer used the official N. R. A. small bore targets, sometimes more or less modified, for the majority of his experimental firing, the card contains a diagram of that target.

This card with a test recorded thereon is shown in Figure 50. It shows a test made with a Winchester Model 70 rifle shooting the .257 Roberts cartridge, covering a series of ten shots fired at 100 yards, from bench rest, with a certain hand load. Going to the filing cabinet, pulling out a drawer, and turning to the cards for this rifle, there can be found the records of firing with all kinds of factory ammunition and about a dozen hand loads, at various dis-

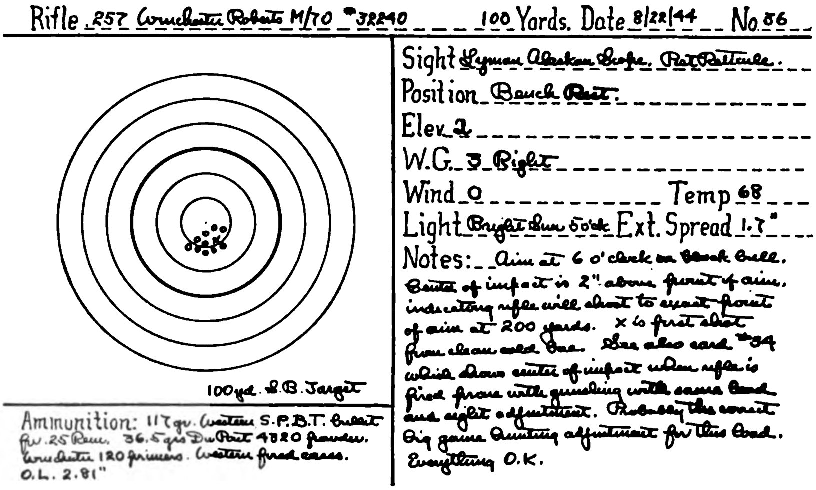


FIGURE 50

One of the writer's 5 x 8 inch record cards, showing the record of a group fired to verify elevation and windage zeros and accuracy prior to fall hunting. Practically every shot the writer has fired in the past twenty-five years has been recorded on these cards, and filed convenient for ready reference. These cards form the basis for much of the information set forth in this work.

tances, under different wind and light conditions and firing positions, and with iron as well as telescope sights—a complete record of all the firing done with this rifle, including also its record on hunting trips, and the effect on various game shot. There are in this file records of four different rifles shooting the .257 Roberts cartridge alone. By adding up the total of the shots recorded, we know how many shots of various kinds of ammunition have been fired through the rifle and thus finally its accuracy life. We know how it maintained its zero from time to time and year to year. We know the accuracy and required sight adjustment for every load.

We learn the accuracy of aim with various forms of sights. We know if the center of impact is the same for shots fired from a clean cold bore as when the barrel is warmed and fouled. In fact, these cards form the basis for much of the information that has been set forth in this work.

Sometimes a group is cut out of a target, the clipping being made 5 x 8 inches, and is filed back of the card to which it pertains, but usually the copy of the group, plotted on the target diagram suffices.

In addition to this card record, a regular correspondence file is kept. Here is set down and filed any other matter for which the cards are not quite suited, sometimes typed or written on ordinary letter paper 8½ x 11 inches, sometimes in the form of letters from riflemen and ballisticians, and sometimes magazine and newspaper clippings. The filing is alphabetical and also according to weapons and calibers.

No other records have been found necessary, except of course those contained in books included in the writer's rather extensive library. These records do not take up an undue amount of space. Two 5 x 8 inch file drawers, each a foot deep, and an 8½ x 11 inch ordinary correspondence file in drawers aggregating about five feet in depth include the records of twenty-five years. These files have paid for themselves a thousand times over.

CHAPTER X

SHOTGUN BALLISTICS

A SHOTGUN is a small-arm, a shoulder arm, designed primarily for the shooting of birds in flight. The reader is asked to bear this definition in mind. What accuracy and velocity are to the rifle and pistol, the *pattern* is to the shotgun. Also we must mention at the start one, or rather a collection of qualities that a shotgun and its ammunition must have to be effective, and this we may term "balance." We do not mean mechanical balance, but rather balance of design and ballistics. These two essentials, pattern and balance, are very closely related.

By the close of the eighteenth century British sportsmen and their gunmakers had determined, by a process of elimination, that a gun to be successful for wing shooting must approach a rather closely defined type. The shotgun must weigh not under six, nor over eight pounds. The barrels should not be less than twenty five, nor more than thirty inches long. The stock should be roughly of a certain shape and dimensions. It must shoot between one and one and a quarter ounces of shot. The velocity must be that given by about three to three and a half drams of black powder. Such were the successful shotguns of the days of Hawker and Manton. These are also the specifications of today. There has been no radical change in over a hundred and fifty years. If we go beyond this balance in either direction the shotgun and its ammunition at once begin to lose their effectiveness for shooting birds on the wing. Since almost the beginning there has been but one noteworthy improvement in the shotgun from the ballistic viewpoint—the choke, which did not begin to appear until about 1874.

The above statement needs certain clarification and justification. As to weight, a shotgun weighing over eight pounds is always too slow and unwieldy for wing shooting. One under six pounds gives unpleasant recoil when loaded with an effective weight of shot propelled at an effective velocity. Barrels at least twenty-five inches long are necessary to burn enough powder to give the shot the velocity needed for sufficient penetration, and also to aline accurately enough when thrown quickly to the shoulder. Lengths

over thirty inches are unnecessary and make the gun too slow and unwieldy for wing shooting. One to one and a quarter ounces of shot are necessary to give sufficient density of pattern to kill birds at thirty to forty yards. More shot at a velocity necessary to give the penetration to kill would make the recoil decidedly objectionable. Also more velocity than that given by the equivalent of three to three and a half drams of black powder makes the shot scatter to such an extent that the pattern is ruined and the gun no longer kills birds effectively. These limitations, this balance, persists to the present day in spite of breech loading and smokeless powder.

Originally, before about 1874, all shotguns were bored a true cylinder—that is, the same diameter of bore from chamber to muzzle. See Volume I. Such guns, irrespective of the diameter of bore, scattered their shot over the area of about a fifty inch circle at forty yards. But the shot was not evenly distributed over this area. There would be spots within this 50-inch circle where a large number of shots would bunch, and other localities where scarcely any pellets struck. If the bird happened to be flying through that portion of the pattern where very few shots were flying it would probably not be killed. The true cylinder bore was therefore not entirely reliable at 40 yards, but at 30 yards the diameter of dispersion was about 37 inches, the pattern was much denser, and the old guns were more reliable.

A goose is a much larger target than a quail, and it also requires deeper penetration of the shot to kill it. As a theoretical measure of effective killing power we say that three pellets of shot should strike a bird to kill it. The larger the pellets of shot, the greater penetration they will have. There are 88 pellets in an ounce of No. 2 shot which gives sufficient penetration for geese, and in an ounce of No. 8 shot there are 409 pellets which give sufficient penetration for quail. Eighty-eight pellets distributed over a 30-inch circle will probably give enough density so that a goose will be struck by at least three pellets. Similarly 409 pellets of No. 8 shot will give a far greater density so that probably a small quail will likewise be struck by at least three pellets. This is the theory of the pattern. The weakness of the old true cylinder bore gun lay in the limitation of the killing range to about thirty yards, and in the uneven distribution of the pattern. No modern shotguns are now bored with a true cylinder, except short barrelled riot guns intended for buckshot only and not for bird shooting.

There is evidence of a choke bore having been tried in shotgun barrels as far back as 1781, but it seems to have been developed to an effective degree by Fred Kimble, an American about 1866, and to have been finally perfected by W. W. Greener, an English gunmaker, about 1874. The choke bored barrel is described in Volume I.

Generally speaking there are four degrees of choke—full, modified or half, quarter and improved cylinder. The effect of the choke is two-fold. First, it confines the dispersion to a much smaller area or circle. Second, it distributes the pellets much more evenly over the area so that there are no close clusters and no large open spaces.

We have already seen that a true cylinder barrel of any gauge or diameter distributes or scatters its pellets over the area inclosed by about a 50-inch circle at 40 yards. The modern choke bore barrel of all gauges distributes about the following percentages of its shot change over a 30-inch circle at 40 yards when fired with a well balanced load:

Full Choke	70%
Modified or Half Choke	60%
Quarter Choke	50%
Improved Cylinder	40%

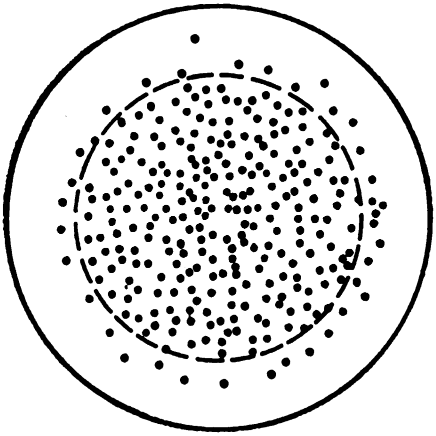
With the full choke, and to some degree with the other chokes, the percentage of the pellets that do not strike within the 30-inch circle probably contain those pellets which have been more or less deformed by violent contact with the bore, particularly the cone and choke of the bore, before they leave the muzzle; and those pellets whose direction of flight have been more or less interfered with by contact with the wadding, particularly the over-shot wad.

But the above tabulation does not tell the complete story of the effectiveness of the various chokes in relation to the probability of killing the bird by the shooter. The following table gives approximately the diameter of the pattern within which the density will be sufficient to kill birds at distances less than 40 yards:

Choke	*20 yds.*	*30 yds.*
Full Choke	20 in.	25 in.
Modified or Half Choke	25 "	35 "
Quarter Choke	30 "	40 "
Improved Cylinder	35 "	45 "

Very much more game is shot at and killed within thirty yards than at over that distance. Any sportsman, and particularly the average and mediocre shot, will hit and kill much more game at thirty yards and under with an improved cylinder gun having an effective dispersion of 45 inches at thirty yards, than with a full choked gun having an effective dispersion of only about 25 inches.

On the other hand the full choked gun will give a pattern dense enough to kill birds surely to forty yards, and often quite well to fifty yards, at which distances the improved cylinder pattern would be much more open, possibly resulting in the bird being struck by only one pellet, or not struck at all. See Figures 51 and 52.



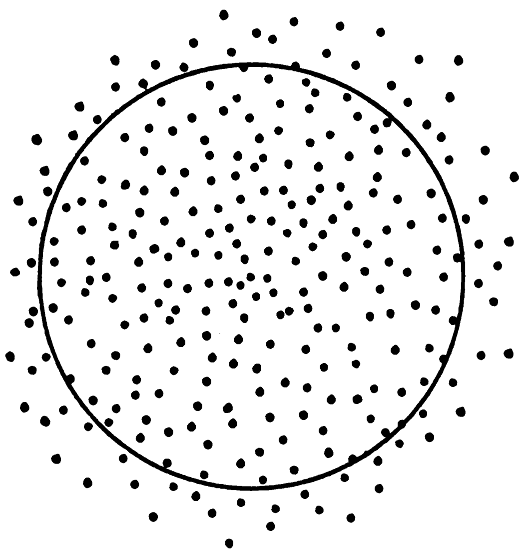


Figure 51

Typical patterns of a 12 gauge full choked gun with 1¼ ounces (279 pellets) of No. 6 chilled shot. Upper at 40 yards, and lower at 20 yards.

The upper pattern shows 70 percent of the shot in the 30-inch circle.

The lower pattern, at 20 yards (at which distance a majority of upland birds are shot) shows almost all the shot in a 20 inch circle. The hunter would have to be a very good shot to hit his birds consistently with this small pattern. He would have a much better chance of hitting at this upland bird distance with the much wider improved cylinder pattern shown in Figure 52.

It is believed that most sportsmen, particularly the unexperienced ones, place more emphasis on the long range quality, that is the full choke, than they do on the increased probability of hitting at the usual ranges given by the quarter choke and the improved cylinder. The gunmaker will furnish guns with any choke desired, and thus every shooter can choose his choke for himself. But, except for special purposes, such as long range duck and goose shooting, a sensible choice in a 12 gauge gun would seem to be—for a double barrel gun for a good shot, quarter choke in the right barrel and modified or half choke in the left; and for the average shot improved cylinder and modified. For a single barrel gun modified choke for the good shot, and quarter choke for the average shot.

The weight of the shot charge, that is the total number of pellets in the charge, naturally effects the density of the pattern, and is of great importance as has been seen. If we consider as a standard of comparison the density of pattern given by a full choked 12 gauge gun shooting 1¼ ounces of shot, then a full choked 16 gauge gun shooting one ounce of shot will give a density of pattern equal to about a modified choke 12 gauge; and a 20 gauge full choked gun shooting ⅞ ounce of shot will give a density equal to about a quarter choked 12 gauge shooting 1¼ ounces. Thus the right barrel of a 20 gauge gun had better be not less than half choke, and the left barrel full choke.

We therefore see the importance of this matter of pattern, its density, its dispersion, and its evenness. It would be fine if we could get a density of pattern sufficient to kill surely at fifty yards and probably at sixty yards. But the only way we can use more shot satisfactorily is by going to a larger gauge or a heavier gun, because of the increased recoil. A nine pound 10 gauge gun, or a 9 pound 12 gauge magnum gun will fire 1⅝ ounce of shot very effectively, but it will be a slow, heavy weapon with which we will miss many shots by not shooting fast enough, and few of us will be pleased with such a gun except perhaps for long range duck shooting.

It would be fine if we could increase the velocity because that would mean less lead necessary on flying birds, and would increase the probability of hitting. But as we increase the velocity we both increase the recoil and we open out or ruin the pattern, so we get nowhere fast. So in both directions, density and velocity, we are limited by the necessity of maintaining our balance—the balanced load of 3 to 3½ equivalent drams of powder with 1 to 1¼ ounces of shot.

As a matter of fact, in addition to the great improvement resulting from choke boring, there has been a recent minor improvement in shotgun ballistics resulting from the development of certain progressive burning or multi-base shotgun powders. Such powders

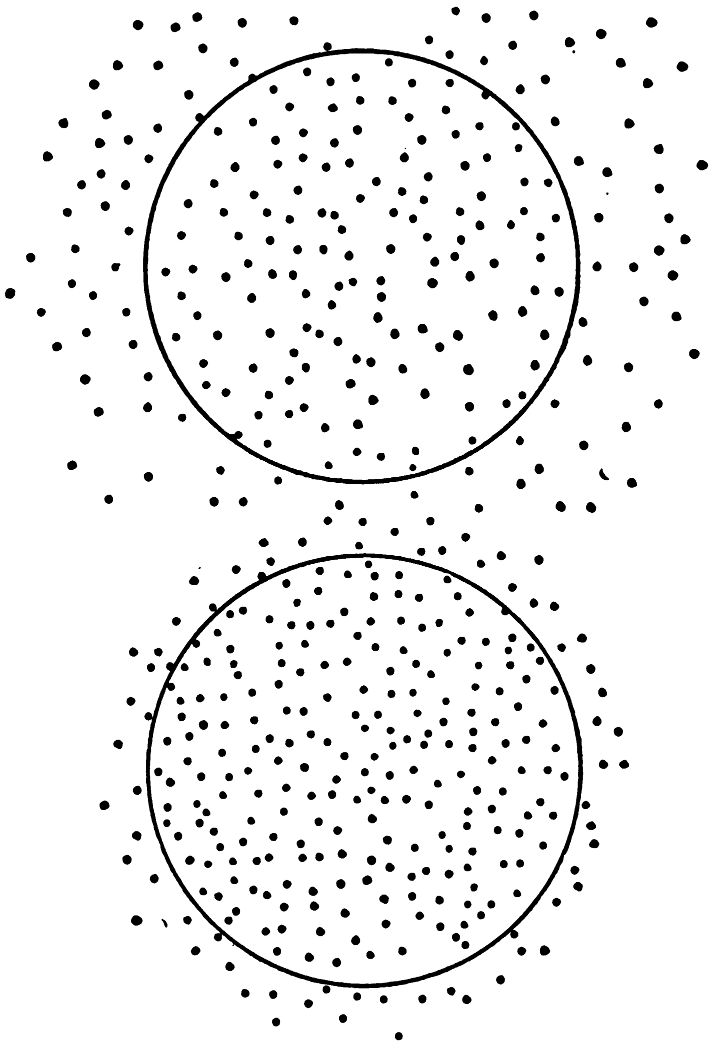


FIGURE 52

Typical patterns of a 12 gauge improved cylinder bore gun with 1¼ ounces (279 pellets) of No. 6 chilled shot. Upper at 40 yards, and lower at 20 yards. The 40 yard pattern shows 50 percent of the shot in a 30 inch circle, the remainder widening the pattern to about 50 inches. The pattern is dense enough to kill well on ducks, and the killing circle is much wider than the full choked pattern shown in Figure 51. But beyond about forty yards the improved cylinder pattern is not dense enough to kill well, while at fifty yards a full choked barrel will give a killing pattern about equal to the forty yard improved cylinder pattern here shown.

give a gradual increase in pressure as compared with the quick blow of earlier powders, and for a given velocity and charge of shot they give less breech pressure. They therefore enable us to accomplish either one of two things. With a certain light charge of shot we can get slightly increased velocity without injuring the pattern. Or with a heavier charge of shot that gives us greater density we can get normal velocity without exceeding the pressure limit, although we will get a slight increase in recoil which may be objectionable to a few. Of the two, increase in weight of charge is much more important than increase in velocity, so loads with the new powder are usually those with a heavier shot charge—1¼ ounces instead of 1⅛ ounces in the 12 gauge for example. These new loadings are usually called "high velocity" loads, which is rather a misnomer. There is usually a very slight increase in velocity it is true, but the great advantage they possess is ability to shoot a heavier charge of shot without loss in effectiveness, and with only a slight increase in recoil.

The above gives briefly the theory of the shotgun, and presents its limitations. We will now discuss the various ballistics in more detail.

Pressure

The pressures of shotgun shells are usually taken with a "radial" or side pressure gauge as described in Chapter III, and illustrated in Figures 7 and 8. The crusher cylinders are of clear lead, .325-inch in diameter and .500-inch long. These cylinders are usually made by each ammunition company for their own use, and are furnished by them to the powder companies for use on their particular components. Pressures are recorded with a .225-inch piston (1/25 of a square inch) located at one inch from the breech or face of the shell. Some pressure barrels are chambered with a standard chamber and forcing cone, and some have tight chambers to prevent gas leakage and record maximum pressures. The tight chambered guns give a smaller loading density (or more correctly "firing density"), but the pressure recorded is probably close to that obtained in a standard shotgun, because the increased volume caused by the movement of the piston probably balances the tight chamber to about equal firing density. But where the pressure gun has a normal chamber, it has been found that the loss in velocity due to the movement of the piston was about 11 f.s. instrumental velocity over forty yards as compared with the normal shotgun.

In the United States shotgun breech pressures are quoted in terms of pounds per square inch, the same as with rifle and metallic ammunition. In England the practice is to quote pressures on the basis of long tons (2240 lbs.).

The ammunition and powder companies do not publish pressures obtained with shotguns and various charges of powder and shot because they vary so much according to conditions, and would be very misleading. Even if pressure guns and methods of taking pressures were completely standardized, there would still be a very great variation given by a certain weight of powder charge and shot, according to the size of the shot, the character and amount of wadding, the loading pressure (on the wads), the make of shell, to what extent the shell is low based or high based, and finally the primer used.

The weight of the shot charge being the same, smaller sizes of shot will give higher pressures. The first thing the powder gas pressure does to the shot charge is to compress it by sending the over-powder and filler wads forward. Small sizes of shot are less difficult to compress individually than large sizes, but a greater amount of work is consumed in compressing due to the greater number of pellets in the load. Then too, with small shot a greater number of pellets are in contact with the walls of the shell, and afterwards with the bore of the gun. The difference between using similar loads of No. 7½ and No. 4 shot is apparently from 400 to 800 pounds.

As a general indication of how pressures may vary, it may be said that with modern factory loaded shells, 12 gauge to .410 bore, they run from about 8,000 to 12,000 pounds per square inch. There is no material difference in pressure between the field, trap, skeet, and high velocity loads when the weight of the shot charge is the same. Heavier charges of powder and shot of course give higher pressures. The 8,000 pound pressure in a 12 gauge shell is about that obtained with 3 equivalent drams of smokeless powder and an ounce of shot. The higher 12,000 pound pressure is about that obtained with the maximum charge of progressive burning powder and 1¼ ounces of shot. In this case, the progressive burning powder in the high velocity shell might record a higher pressure, but the pressure would be applied more gradually, and would not give that shock and disturbance to the shot column that usually results in a poor pattern when the pressure is high.

Shotgun shell pressures with normal factory loadings of black powder, that is, with the shells we used to buy forty to fifty years ago, ran about 4,000 to 5,000 pounds, and seldom if ever exceeded 6,000 pounds. For such pressures the older Damascus, laminated, and twist barrels had ample strength, but such barrels are absolutely inadequate and unsafe when used with the modern smokeless shells of today with twice the pressure. An accident is bound to occur sooner or later. See Volume I.

There are four factors which place the limit on the amount of breech pressure that will be safe. One is the steel of which the barrel

and action are made. With modern guns by reputable makers, even the cheapest single barrel gun at present retailing at about $15.00, the steel is almost always of adequate strength. Then the wall thickness of the barrel or barrels is always a limitation, because this has to be relatively thin to keep the weight down to a handy figure. The inherent weakness of the paper shell as compared with the much stronger brass cases used in rifle and pistol ammunition is the third factor. And the fourth is the necessity of obtaining a close and evenly distributed pattern, which is utterly ruined when pressure is too high. The ammunition companies, when furnishing factory loaded shells, keep their pressures well within the limits of safety and good patterns, for naturally their reputation and financial success depends upon so doing.

Velocity

It is the common practice in the United States to determine the velocity of a shot charge over a measured range of forty yards. It is neither necessary nor helpful to convert the chronograph readings to muzzle velocities, as is usually done with rifle and pistol ammunition. The very light shot pellet, with its poor coefficient of form, loses velocity very fast from air resistance, small shot also lose velocity much faster than larger shot, and muzzle velocity would give a very erroneous impression of the time of flight over the usual shotgun range.

Shotgun velocities are commonly taken with the Le Boulenge chronograph, or now perhaps with a more modern chronograph or chronoscope. One disjunctor is placed at the muzzle of the gun and the other immediately back of the forty yard target. The instrumental velocity registered in foot seconds is thus the mean velocity of travel over forty yards.

Because the shot charge consists of many pellets, velocity cannot be determined with such exactitude as with a single projectile as in rifle and pistol ammunition. When the shot charge leaves the muzzle it has a tendency to string out lengthwise along the line of flight, and this stringing out increases as the distance increases, the shot stringing out as much as 12 to 18 feet by the time the 40 yard target is reached. The first pellet, or the first two or three pellets to reach the terminal target will operate the disjunctor, and therefore the velocity recorded is that of the fastest flying pellets. Also, as we have seen, larger shot overcome resistance of the air better than small sizes, and where the two start with the same muzzle velocity, the time of flight over forty yards will be much smaller for the larger sizes.

The Dram Equivalent. A charge of a certain weight of one kind of smokeless powder may give very different results and velocity than the same weight of another kind of powder when all other

conditions are the same. Therefore it has become the practice in the United States, when referring to velocities and patterns, to give the powder charge in terms of "equivalent drams." This is the amount of powder, either bulk or dense, which will develop the same uniform velocity in shells of the same bore.

In the days of black powder the top, over-shot wad was stamped with the powder charge, shot charge, and size of shot, as "3¼-1 ⅛-6. Sportsmen became used to this, and knew just what results they obtained from various charges of powder and shot. The early smokeless powders were manufactured so that a charge of three drams bulk measure (not weight) gave the same power and velocity as three drams bulk measure of black powder, and the system of marking the top wad was continued. As smokeless powders were improved, however, they became more and more dense, so that a three dram bulk measure was much more powerful than the corresponding amount of black powder, and the standard charges of these dense powders had to be considerably reduced. But it was considered very desirable to continue the marking of the top wad, which gave information that all shooters had come to look for. The loading companies accordingly developed certain standard velocities for their modern smokeless loads, and all modern shells are loaded to develop these standard velocities, and the wads are still stamped with the equivalent dram measure that produces approximately the same velocity that black powder did, only a slightly new standard was adopted. As an example the present standard trap load of 3 equivalent drams, and 1¼ ounces of No. 7½ shot has been assigned an average standard velocity of 850 f.s. over 40 yards, regardless of what powder is used, or what that powder charge weighs. As a matter of fact the powder charge of three equivalent drams may weigh anywhere between 25 and 50 grains depending on the powder used. The table of standard velocities for 12 gauge loads on page 197 will make this matter of the dram equivalent clear.

The last two lines in the table on page 197 refer to maximum loads of multi-base progressive powder, being the standards for the commonly called "High Velocity," or "Super" loads.

In other gauges, 16 to 410, the velocities from lightest to heaviest loads, do not differ materially from the 12 gauge velocities.

Note that the larger sizes of shot give greater velocities over 40 yards, although the muzzle velocities are about the same, due to their overcoming air resistance better, as has already been explained.

In England the system of standardized loads is radically different. Modern British smokeless shotgun powders are generally divided into two types. One type is called a "33 grain powder" because the amount required to fill a 3-dram black powder measure weighs exactly 33 grains. The other type is called a "42 grain powder" because

Standard Velocities for 12 Gauge Standard Loads

Dram Equivalent	Shot Ozs.	*Velocities Over 40-Yard Range in f.s. ± 10 Feet*							
		Shot Size							
		2	*4*	*5*	*6*	*7*	*7½*	*8*	*9*
2¾	1⅛	945	915	895	875	850	840	825	785
3	1	995	965	945	925	900	890	875	835
3	1⅛	975	945	925	905	880	870	855	815
3	1¼	955	925	905	885	860	850	835	795
3⅛	1¼	970	940	920	900	875	865	850	810
3¼	1⅛	1,005	975	955	935	910	900	885	845
3¼	1¼	985	955	935	915	890	880	865	825
3½	1	1,055	1,025	1,005	985	960	950	935	895
3½	1⅛	1,035	1,005	985	965	940	930	915	875
3½	1¼	1,015	986	965	945	920	910	895	855
Max. 2¾" Shell	1¼	1,040	1,010	990	970	945	935	920	880
Max. 3" Shell	1⅜	1,025	995	975	955	930	920	905	865

that amount is required to exactly fill the 3 dram black powder measure. The 33 grain powders are "E.C.," "Empire," "Nobel Smokeless" and "Smokeless Diamond." The 42 grain powders are "Amberite" and "Schultze."

British velocities are taken over the first twenty yards of range, and the standard loads give between 1000 and 1100 f.s. over that distance, or an average of 1050 f.s. The velocity taken over this 20 yard range is called the "Observed Velocity." They have more or less standardized on this observed velocity of 1050 f.s. and consider that it gives as good an all-round load as can be desired for game shooting. With this observed velocity, rather akin to our muzzle velocity, the actual remaining velocity will vary with different sizes of shot for the reason already stated above. So the English ammunition maker publishes tables giving the actual remaining velocities over ranges from 10 to 60 yards for all sizes of shot, for the observed velocity of 1050 f.s. Other tables are also given for other observed velocities from 850 to 1200 f.s., should anyone desire to have shells loaded specially to these observed velocities to attain less or more than the standard striking velocities. British shells loaded to the standard observed velocity of 1050 f.s. give actual velocities over 40 yards slightly lower than our standard factory loads. That is, the British load to a slightly lower standard velocity than we do. Pattern is more important than a slight increase in velocity, and it is probable that the British loadings give the best patterns in guns bored and choked

by British gunmakers, while ours give the best patterns in our American shotguns.

High Velocity Loads. If we desire to increase the probability of hitting and killing we had better direct our efforts to increasing the amount of shot fired, that is the number of pellets per load which will give us a denser pattern, rather than to try to increase the velocity, which is already high enough to give us all the needed penetration. With most powders, however, if we increase the weight of the shot charge we increase pressure and recoil to a very undesirable extent. The development of the modern multi-base progressive powders have, however, permitted us to increase the amount of shot without increasing the pressure, and we utilize these powders for our maximum loads, which are commonly called "High Velocity," "Super X," or "Super-Speed" loads. The term high velocity is really slightly a misnomer. From the above table of standard velocities it will be seen that the velocities of these standard maximum loads are not materially greater than the standard 3½ dram 1¼ ounce load. The recoil is slightly increased, but usually not to an uncomfortable degree. These maximum loads are particularly indicated for long range duck and goose shooting.

The very highest efficiency in a shotgun load is obtained with the 12 gauge 3-inch, high velocity or maximum load. The ordinary American 12 gauge gun is chambered for 2¾ inch shells, and this 3-inch shell cannot be used in them. It is intended for use in certain special heavy guns that are chambered for it, and are termed "Heavy Duck Guns," or "12 gauge Magnum Guns." The shell carries 1⅜ ounces of shot, at the maximum velocity as shown on the last line of the above table of standard loads. The gun must weigh over 8 pounds or the recoil will be excessive. It also should have 30 or 32 inch barrels to burn sufficient of the powder to give the standard velocity. Such shells are intended only for long range duck, goose, and wild turkey shooting. For other use the gun is heavy, slow, and unwieldy, the recoil heavy, and the cost greater. Three-inch shells should never be used in a standard shotgun chambered for 2¾ inch shells. The mouth of the shell is pinched in by the cone of the shorter chamber, resulting in very excessive pressure and a ruined pattern. The standard 2¾ inch shell, can be used in a gun chambered for 3-inch shells, and in a full choked barrel will give about modified cylinder patterns, the pattern "opening up" slightly.

Field, Trap, and Skeet Loads. For ordinary use on upland birds, which are invariably shot within 40, and commonly within 20 to 30 yards, and for trap and skeet shooting, the above maximum loads are entirely unnecessary. Their recoil and expense are objectionable, and they add nothing to the effectiveness. For such use the well in-

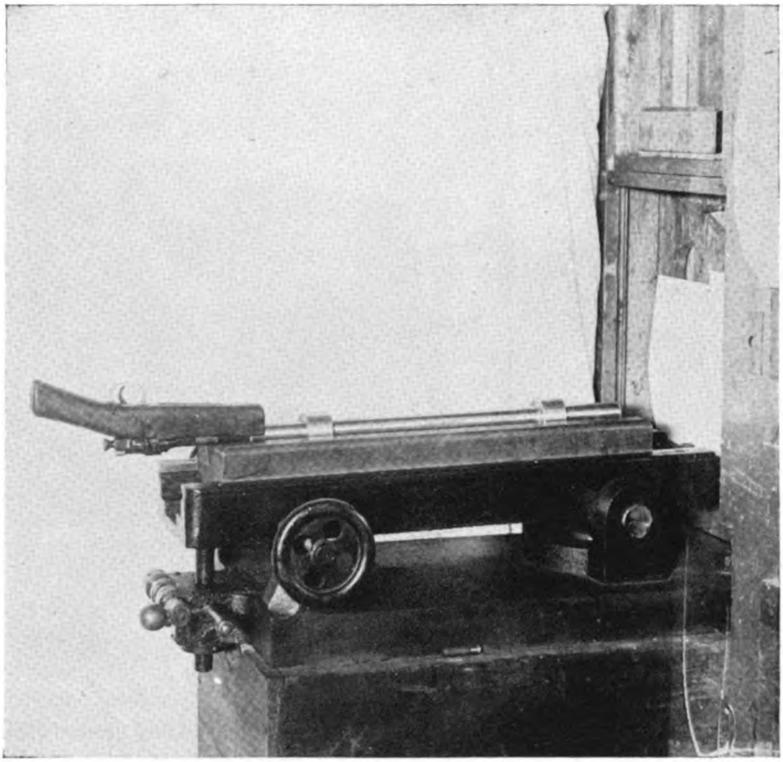


Figure 44

The Mann "V" Rest, showing the Mann barrel in firing position. The heavy V block is held in the adjustable base of the Frankford Arsenal Rest. It is the only method of firing that is absolutely free from human error. It is not applicable to modern and normal rifles, and is used only for ammunition testing and experiment.

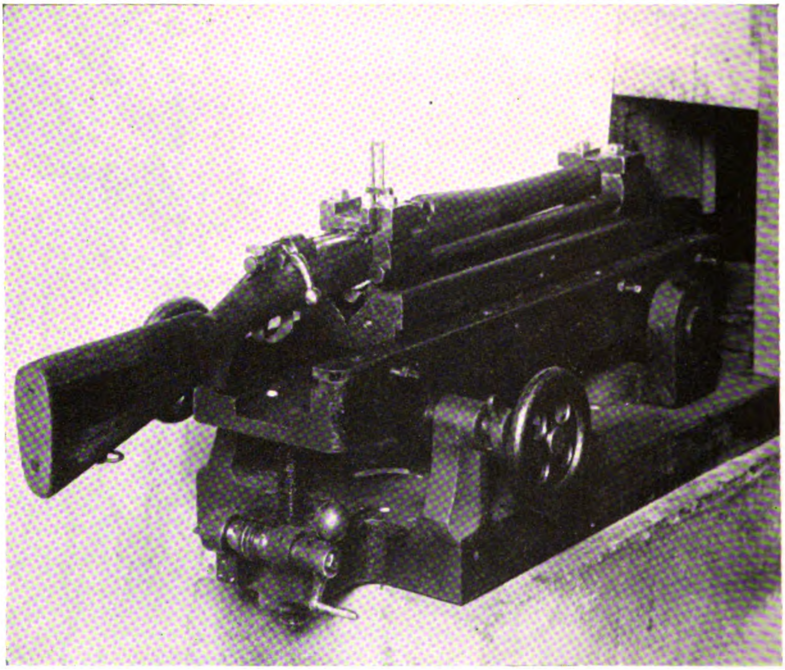


FIGURE 45

The Woodworth Cradle used in the Mann V Rest for holding normal rifles, showing the cradle arranged for the Springfield 1903 rifle. It would be possible to build a cradle to hold almost any rifle, although at considerable expense. This cradle, when used by a skilled operator, is almost free from human error. It will prove the accuracy of an individual rifle, or the accuracy of ammunition fired from a normal rifle, but it is not satisfactory for "sighting in" a rifle.

formed shooter prefers the lighter and pleasanter loads known as Field, Trap, and Skeet loads. In 12 gauge such a load generally consists of 3 to 3¼ drams equivalent and 1⅛ ounces of shot.

Barrel Length

At the beginning of this chapter it was stated that the barrel of a shotgun should be not less than twenty-five, nor more than thirty inches long. Many shooters believe that the longer the barrel the greater the penetration and the denser the pattern, but generally speaking this is not so, at least to any appreciable extent.

The 12 gauge standard velocities, as given in the preceding table, are obtained with a barrel 30 inches long. When the barrel is shortened there is a loss in instrumental velocity of about 7½ f.s. per inch down to 25 inches. Below 25 inches the decrease per inch is very much faster. Thus a 26 inch barrel, the shortest American barrel commonly furnished, would give only about 30 f.s. less instrumental velocity than a 30 inch barrel. But the difference in striking energy and consequently in penetration would be so little as to be unnoticeable. Where the choke is the same, there is no difference in the average patterns given by 26 and 30 inch barrels. Between these lengths the selection should be made to obtain the desired balance, swing, timing, and handiness rather than on ballistic efficiency.

The shortest shotgun barrels commonly supplied by American manufacturers is 26 inches, and the longest 32 inches, but in England many shotguns are made with barrels as short as 25 inches. Below 25 inches muzzle blast, report, and recoil increase to a very undesirable extent, and velocity and penetration fall off appreciably. Except for long range duck guns, the most popular and sensible barrel lengths are 12 gauge—28 inches, 16 gauge—26 or 28 inches, and 20 gauge and under—26 inches.

Barrel Time

Barrel time is the interval from the time the shot starts forward until it leaves the muzzle of the gun. Formerly it was measured with a chronograph with electrical disjunction at the firing pin and muzzle, but this method was not very accurate due to the limitations of the older chronographs, and the difficulty of establishing an absolute zero with the firing pin. In modern laboratories it is measured with an oscillograph. A pressure gun is fitted with a Piezo electric crystal which generates a current proportional to the pressure when the gun is fired. The current flows through the cathode-ray tube of the oscillograph where it deflects a beam of light which is registered photographically. The curves of the beam on the negative are recorded in pressure-time units from which can be read the pressure at

any time interval, the acceleration of the shot charge, the velocity at any given point in the barrel, the pressure at any point, and the barrel time.

The following tabulation shows the various time intervals of a 12 gauge gun loaded with 1¼ ounces of No. 7½ shot to a standard velocity over 40 yards of 855 f.s. ± 20 f.s.:

Type of Powder	*Kind of Powder*	*Barrel Time sec.*	*Trigger to Muzzle Time sec.*	*Muzzle to Target Time sec.*	*Trigger to Target Time sec.*
Nitrocellulose	duP. Smokeless	.0033	.007696	.140996	.148692
Nitrocellulose	duP. Oval.	.0035	—	—	—
Nitroglycerin	Ballistite	.0027	—	—	—
Multi-Base	duP. M.X.	.0030	.008013	.140189	.148202

One important factor in barrel time is the primer. A test with du Pont M.X. powder showed a difference of .0003 second with two makes of suitable primers.

These time intervals are very short, and the difference between them is extremely small, so that a human being cannot appreciate them. The eye is more sensitive to time reaction than any other sense of the body, but even it cannot register a time interval shorter than 1/11 second. In movies, 16 pictures are projected each second, and no jerky motion can be seen, the picture being a smooth continuous action because the time intervals between the pictures is less than 1/11 second. However, we can perhaps in a way visualize the trigger to target time, approximately .15 second or 1/7 second as appearing to us as "quick as a flash."

Jump and Vibration

The movements of the shotgun before the charge leaves the muzzle are similar to those with the rifle as described in Chapter IV. When the gun is fired from the shoulder the breech rises and the muzzle dips down, this being the jump. The reacting vibration throws the muzzle up, and as the recoil is usually heavier than with the rifle, and the barrel time longer, the upward vibration occurs before the shot charge departs from the muzzle. Therefore at short distances the shot charge strikes, or centers itself, above the prolongation of the bore at rest. With double barrel guns there is a secondary vibration movement in a horizontal plane due to the axes of the bores being located to one side of the center of mass. Different loads will cause a different jump and vibration, but the practical effect is small because a variation of several inches in the location of the center of the pattern can have little effect in striking the target with the pattern at least fairly centered on it. Jump and

vibration are of more importance to the gunmaker than to the shooter, for the former has to control his line of sight so that the gun will be sighted approximately correctly for all standard loads.

Recoil has been described in Chapter IV, and it will suffice here to merely mention again that the load and the weight of the gun should be such that the recoil is not punishing. The shotgun shooter should be able to fire twenty-five to two-hundred rounds a day without discomfort.

Shot

Tables showing the size and diameter of the different sizes of American and British shot pellets are given in the Appendix, as well as a table showing the number of pellets of each size in an ounce weight. Shot is measured by weighing, or by measuring with a dip measure, or a mechanical measure, or by counting the pellets. Usually a mechanical measure is used, its adjustment being verified by a scale.

Shot is made of lead, as it has a greater density (weight for bulk) than any other cheap metal. Maintenance of velocity, penetration, and killing power are dependant on high density. The molten lead is poured slowly through sieves, with holes according to the size shot desired, and the drops coming through the holes fall through the air from a great height in a shot tower, finally falling into water where the drops are cooled. The resulting shot are then collected from the water, sifted through screens, and the imperfect and out-of-round pellets culled out automatically by machinery.

There are three general kinds of shot.

1. Soft or drop shot.
2. Chilled or hard shot.
3. Coated or plated shot.

Soft or Drop Shot is made of pure or nearly pure lead, to which a small amount of arsenic has been added to make it take on the form of a spherical drop as it falls down the shot tower. Soft shot is more easily deformed in the bore of the gun than either chilled or coated shot, and it leads the gun barrel more. The pattern is not so good, particularly with choke bored guns. Those pellets which have been deformed or flattened lose their velocity quicker, string out more, do not have as deep penetration, and hence do not kill so well. However, where the pellet is not deformed, and hence is flying at higher velocity, it tends to flatten more when it enters game, makes a larger wound, and most sportsmen think that soft shot are on the whole slightly superior to chilled or plated shot in killing power. But the pattern is much more important, and probably soft shot will become more or less obsolete after the war.

Chilled or Hard Shot has a small amount of antimony incor-

porated with the lead, which increases its hardness. As compared with soft shot it does not deform so much in the bore, gives better patterns and less stringing, the velocity and penetration are more uniform, and it does not lead the barrel so much.

Coated or Plated Shot, called by one manufacturer "Lubaloy" shot, is chilled shot that has been given a thin coat of copper, by electroplating. The coating gives the pellets greater strength and elasticity. The result is increased resistance to deformation, the pattern is better, and it does not lead the barrel as much as soft or chilled shot. The only drawback is a slight additional expense.

Killing Power

We have already seen that with standard shells the remaining velocity at all distances, while not actually the same, is so nearly so that differences can be disregarded. This is also true of the difference in velocity between different sizes of shot. We can therefore say that, practically, killing power depends upon the size of the shot. The larger the birds we are hunting, the greater the killing power needed, hence we use larger shot for larger birds. The following table shows the size of shot that experience has shown to be best for different species of American game birds:

	Size of shot
Geese and wild turkey	2 or BB
Late ducks over decoys. All pass ducks	4
Early ducks over decoys	5 or 6
Pheasants, prairie chickens, grouse, squirrels, and rabbits	5, 6, or 7
Late season quail, doves, etc.	7, 7½ or 8
Early quail, small shore birds, snipe, rail, woodcock	8 or 9
For trap shooting	7½
For skeet shooting	9

Besides the penetration and killing power of the individual pellets, the relationship of shot size to bird size also works out correctly in another way. We say that three pellets should theoretically strike a bird to kill it. This is not absolutely true. Many birds are killed dead with a single pellet. But the former has proved to be a fairly good guide. The smaller the size of shot the denser the pattern where the weight of the shot charge is the same. With No. 2 shot there are 88 pellets to an ounce. A full choked gun will distribute about seventy percent of these over a thirty inch circle at forty yards. There will probably be no space in that pattern where the large body of a goose would not be struck by at least three pellets, but there will be many places in this pattern, where if a quail happened to be flying as the pattern passed it, the quail would be struck by only one pellet or not be struck at all. On the other hand there are 409 pellets

in an ounce of No. 8 shot which we use for quail, the pattern is very much denser, and there will probably be no spot in it where a quail would not be struck by at least three pellets. But No. 8 shot would hardly have enough penetration to do much damage to a goose. The diameters of these shot are No. 8—.09-inch, and No. 2—.15-inch.

Pattern

The "pattern" of a shotgun and its load is the dispersion of the shot holes made in a sheet of paper when fired on at a specified distance. The pattern is judged by its diameter, by the percentage of the total number of pellets in the load which strike within the circle, and by the evenness of dispersion within the circle. The problem of hitting the bird depends on all of these factors. What accuracy is to the rifle and pistol, the pattern is to the shotgun.

It is almost universal practice in the United States to pattern all standard shotguns of 10 to 28 gauge at 40 yards. The gun is fired at a large sheet of paper, set up at that distance, aim being taken at the center of the sheet. The shot holes form a more or less round group, or pattern, on the paper. Using the apparent center of this group, a circle 30 inches in diameter is then drawn on the paper, and the number of shot holes falling within this circle are counted, and the percentage that this total bears to the total number of pellets in the load is calculated. The table of chokes at the beginning of this chapter shows the average percentage of shot that should strike within this 30 inch circle, with guns of various degrees of choke. This is an average of ten or more patterns. Any one pattern may be slightly higher or much lower than the given percentage. For a full choked gun, for example, the average pattern should be about 70 percent, but individual patterns may run all the way from 85 to 50 percent. There is a little variation between individual guns and makes of shells. There is not, however, nearly as much variation between the very cheap guns and the most expensive ones as a person might expect. Some individual guns of the same make will show a closer pattern with the same shells than other guns. It is quite common for one gun to pattern much better with one make of shell than with another. As yet, no one make of shell, nor any one make of gun has shown decided average superiority in pattern over others. Yet it may also be said that the better grades of shells loaded with progressive powders, shot in the higher grades of shotguns do show a slightly better average of patterns than other combinations, which is to be expected. Some guns show a decided tendency to pattern better with one size of shot than with others. Larger sizes of shot tend to produce patterns of a higher percentage than small shot. We cannot, therefore, make an unqualified statement that a full choke gun will pattern seventy percent. It may or it may

not, but good guns shot with good factory loaded shells should come pretty close to that average, particularly with the larger sizes of shot. See the table on page 205.

We occasionally hear of a gun which has averaged 80% patterns. It is probable that such a gun will not repeat such an average a week or a year later.

Skeet guns and skeet loads are patterned at 25 yards. Pellets are counted within a 30 inch circle. Under these conditions the patterns should approximate 65 percent.

410-bore guns are tested for pattern at 25 or 30 yards, counting the pellets within a 20-inch circle. Almost all 410 bore guns are full choked, and should pattern about 65 percent within the 20 inch circle at 30 yards. Of course the pattern within the circle will not be particularly dense, because 410 shells are normally loaded with only ½ to ¾ ounces of shot.

Similarly 12 gauge shells will show denser patterns than 16 or 20 gauge shells, but the percentage should average the same. For example, with No. 7½ shot the 12 gauge shell may be loaded with 1¼ ounces which is 422 pellets, and that shell may average a pattern of 296 shot holes within the 30 inch circle which is a 70 percent pattern. The 20 gauge shell may be loaded with ⅞ ounce of No. 7½ shot which is 296 pellets, and may show 207 shot holes within the 30 inch circle, which is also 70 percent.

The tabulation on page 205 has been approved by the Technical Committee of the Sporting Arms and Ammunition Manufacturers Institute with a tolerance of $\pm$ 5%, showing the nominal expected patterns from various load combinations and chokes. It is intended as a guide for the various manufacturers to secure uniformity and high quality of their goods, and not as a basis for comparative test. To some extent it represents a goal which manufacturers endeavor to reach, and which, from experience, is attainable by careful workmanship.

Importance of Patterning. Strange to say sportsmen seldom pattern their shotguns. They seem to take it for granted that the gun they buy will shoot a dense pattern according to its choke, that it will center this pattern where the gun is aimed, and that, in the case of a double barrel gun, both barrels will center their pattern equally well on the point of aim. Such things cannot be taken for granted. It is true that our shotguns are wonderfully uniform and well made, but defects and inaccuracies can and do occur. It is not usual that guns will give absolutely poor patterns with good makes of shells, but often they will pattern with one make of shell, or one size of shot better than with others. More likely, but still rather rare, they will not center their patterns on the point of aim, or two barrels may cross-fire.

Shotshell Patterns
Standard Full Choke Barrel
Chilled Shot—Range 40 Yds.-30″ Circle

Gauge	*Lgth. of Shell in Inches*	*Lgth. of Chamber*	*Dram Equiv.*	*Shot Wt. in Oz.*	*Size of Shot and Percentage Pattern* #2	#4	#5	#6	#7	#7½	#8	#9	#10
12	2¾	2¾	2¾	1⅛						73	72		
12	2⅝	"	3	1		75	74	73	71		68		
12	" & 2¾	"	3	1⅛		72	71	70	68	67	66	64	62
12	2¾	"	3	1¼						70	69		
12	2¾	"	3⅛	1¼						68			
12	2⅝	"	3¼	1⅛	70	68	67	66	64	63	62		
12	2¾	"	3¼	1¼					64	63			
12	2¾	"	3¾	1¼	74	72	71	70	68	67			
12	3	3	3¾	1¼					72	71			
12	3	3	4	1⅜	74	72	71	70					
12	3	3	4¼	1⅝	72	70	69	68					
16	2 9/16	2¾	2½	1		72	71	70	68	66	64	62	60
16	"	"	2¾	1		70	69	68	66	64	62	60	
16	" & 2¾	"	2¾	1⅛							64		
16	2 9/16	"	3	1⅛	72	70	69	68	66	64			
16	2¾	"	3¼	1⅛		72	71	70	68	66			
20	2½	2¾	2¼	⅞		69	68	67	65	63	61	59	57
20	" & 2¾	"	2½	1							60		
20	2½	"	2¾	1		70	69	68		65			
20	2¾	"	2¾	1	72	70	69	68	66	65	62		

Modified Choke Patterns 80% of above
Improved Cylinder " 65% " "
Cylinder Bore " 60% " "

	Soft Shot Correction, Full Choke Barrel								
Minus	5	6	7	8	9	10	10	10	10

No one knowing anything about rifles would think of going hunting with a new or strange rifle until he had sighted it in, adjusted the sights if necessary, and assured himself that it will hit where he aims. But strangely enough it seldom occurs to a sportsman to do the same with his shotgun. Sportsmen commonly try their guns only on birds or at the trap. If they do not kill consistently with it, or make good scores, they say that the gun does not fit them, and they proceed to alter the stock, or they buy a new gun. In many such cases the fault is not always with the stock or the choke. It may be because the gun does not center its patterns where the shooter aims it.

Ordinarily, when a gun is patterned at the factory or by a shooter, the almost universal practice has been to fire it at a large sheet of

paper placed forty yards away. Then a point is selected at what appears to be the center or densest portion of the pattern, and on this point as a center, with a radius of 15 inches, a 30 inch circle is drawn around the pattern. The number of shotholes within this pattern are then counted, and if the count comes up to the established percentage according to the choke of the gun, the pattern is said to be satisfactory. Now this is no proof that the gun is centering its pattern where the sportsman will aim it. As a matter of fact the pattern center is sometimes far from where the gun was aimed, high, low, right, or left, and when the sportsman aims such a gun correctly he will miss many birds with it. If the pattern center was off aim five inches at forty yards it would decrease the effectiveness of the gun about fifteen percent.

In patterning a shotgun the sportsman should aim it deliberately, steadily, and carefully at a small bullseye placed in the center of the pattern sheet, and he should be careful of his trigger squeeze. Then he should use the center of the bullseye as the center from which to draw his 30-inch circle. A shotgun should center its pattern, either on the bullseye, or at a point not more than eight inches above it. Some prefer to have their guns pattern dead on, and some a little high. The factory tries to make their guns to center either dead on or not more than eight inches high. Usually they succeed, but sometimes they do not. Cheap and medium priced guns are seldom tested one hundred percent to see that the pattern centers on the point of aim. Uniformity of manufacture is supposed to attend to this, but it does not always do so. And even so, the tester at the factory may not aim the gun in the same way that the eventual owner will.

It is obvious that a factory cannot make its guns to center their patterns on the point of aim unless the gun is properly aimed; unless there shall be some standard of aim. A shotgun has no rear sight; the shooter's eye is the rear sight. It is generally assumed that a shotgun is correctly aimed when the shooter's head is so held by cheek contact with the comb and left side of the stock, that the line of sight from the pupil of his eye to the front sight passes about a quarter of an inch over the standing breech, or rear end of the rib of the gun, so that an abbreviated view of the rib or top of the barrel can just be seen. The shooter should select a gun with such a fit of stock that when he mounts the gun to his shoulder and cheeks the stock naturally, his eye will come naturally into such a position relative to the gun that he will see the front sight, barrel, rib, and standing breech alined in this manner. Then, as thus aimed, the gun should center its pattern as the sportsman wishes, on the bullseye, or a little above it.

He can only alter this line of aim by so altering the drop of the

stock, and its thickness and height at the comb, so that his eye naturally comes a little higher or lower than this quarter inch above the standing breech. If the barrel is 30 inches long, then there are 1440 inches in 40 yards, into which 30 inches goes 48 times. Therefore every one hundredth of an inch lower or higher than this quarter inch above the standing breech will make a difference of about a half inch in alinement at 40 yards. Thus changing the stock so that the eye is directed an eighth inch higher or lower over the standing breech will change the sight adjustment and the location of the pattern about six inches at 40 yards. This is not theory. These are facts that cannot be altered. It is pretty hard for a shooter to tell within an eighth of an inch of where his line of sight comes above the standing breech, and it is likewise difficult for the factory to tell how the eventual owner of their gun is going to aim. Remember that an eighth of an inch difference in the position of the eye-rearsight makes a difference of about six inches at 40 yards.

So in patterning the aim must be correct, and the let-off without jerk or flinch. This cannot be positively assured when firing in the customary standing position any more than the rifleman can always be sure of hitting the bullseye when shooting offhand. The sportsman should sit down behind a table, rest both elbows on the table (the gun however not being rested) and he should be most careful of aim and trigger press. There must be no jerk or flinch.

If the gun patterns too high or low it is possible that the gun itself may be at fault, but it is more likely that if the pattern center is high above the point of aim the comb of the stock is too high and has directed the eye-rearsight too high. In that case a gunsmith can shave down the comb a little. If the pattern is too low, then the comb must be built up, which a skilled stocker can also do, or a cheek pad might be laced on the comb. If the owner of the gun objects to such disfigurement of the stock the gun can be returned to the factory for a stock that is higher at the comb. Many men also change the drop at the heel, and the pitch of the butt-plate to accomplish such changes in the natural alinement of the stock. The writer, however, believes that the comb is the critical portion of the stock, and that nothing can be accomplished very surely at the butt end for the position here is materially changed by every change in the clothing the shooter wears.

If, however, the gun shoots consistently to the right or left, and the shooter is certain that his line of sight is passing central over the breech, then there is nothing that can be done but send the gun back to the maker for correction or to be exchanged for another gun. If the tendency is for the eye to aline to the right or the left, then a little padding or shaving down of the proper side of the comb and the stock will correct this.

With a double barrel gun, test both barrels. They may not shoot alike. They may cross-fire. If they do there is nothing to be done but send the gun back to the factory.

Shot Stringing

When the shot charge leaves the muzzle it not only spreads laterally, but it also "strings" longitudinally. The late Philip P. Quayle, of the Peters Cartridge Company, was the first to accurately record shot stringing by means of spark photography, and he gave us our first accurate knowledge of the matter. The longitudinal stringing of the shot has no relationship to the pattern or lateral dispersion, but the same factors that influence the spread also influence the stringing. Briefly, the stringing of the shot is caused by the deformation of the pellets while in the barrel, particularly as they pass through the cone and choke. The type of powder used, and the top over-shot wad also influence stringing.

With ordinary powders, when the first pellets reach the 40 yard target, the shot charge is strung out for about 18 feet in length to the rear, when shooting the best quality of factory loaded shells in a choke bored gun. This is roughly 1½ feet for every 10 feet of range. That is, at 30 yards, perhaps the average distance at which birds are shot, the string will be about 13 feet long.

With progressive burning powders, the acceleration of pressure in the barrel is more gradual, more of a push than a blow, the pellets are not deformed quite so much, and the stringing is only about 12 feet at 40 yards, or one foot for every ten feet.

In chronographing a charge of shot it is the first pellets that strike the target disjunctor that record the velocity. The average factory loaded shell, all gauges, gives an average velocity over 40 yards of about 880 f.s. This is the velocity of the first shot pellets in the string. The striking, or remaining velocity, at 40 yards is about 800 f.s. Therefore the rearmost pellets in the string will have a striking velocity of about 600 to 650 feet per second.

The effect of the stringing on the number of pellets that have a chance of striking a flying bird is not so disastrous as would at first be apparent. If the bird is flying straight towards or straight away from the shooter, the maximum number of pellets will be effective. On the other hand, if the bird is flying fast across the shooter's front at a right angle, and the shooter has taken a lead correct for the first pellets in the string, then those in the rear of the string will pass in rear of the bird. On the other hand, if the lead has been a little excessive, the first pellets will pass in front of the bird, and the rear pellets will strike it. The bird will not be struck quite so hard by these rear pellets, but almost always hard enough to penetrate well, and it will be struck and not missed.

Long stringing is a disadvantage, but it is debatable whether the short stringing given by progressive powders is. It may be that our best wing shots habitually take a little more lead than is necessary for the first pellets in the string, and where that is the case, stringing is an advantage. Thus the chief disadvantage is that the bird may be struck only by the rearmost pellets flying at lower velocity and may be only wounded.

The Top Wad and the Crimp. When taking a series of patterns, every once in a while an extremely poor pattern will occur. The count is small, and there will be a big gap in the pattern. This is called a "blown pattern" and is usually caused by a number of the shot colliding with the top over-shot wad after the charge leaves the muzzle. Recently American manufacturers have introduced a new crimp. The top wad has been eliminated entirely, and the mouth of the paper shell is crimped directly over the shot charge. When the shell is fired the crimp irons out, and there is nothing ahead of the shot as it passes up the bore and out the muzzle. This new crimp has almost entirely eliminated the blown pattern.

Brush Shells. These have been developed by the manufacturers for use in choke bored guns to open out the pattern. They enable the shooter to use his choke bored gun to better advantage on upland birds, and particularly birds in dense cover. In a choke bored barrel they give a pattern about equal to an improved cylinder. Twenty-two yards is about the average distance at which upland birds are killed, and at this distance the pattern of a full choked gun is only about 21 inches in diameter, but is increased to about 36 inches by using a brush shell.

Brush or spreader shells are made in two ways. One way is to divide the shot charge into three parts by using top wads between the parts. Another method is to place a cross shaped cardboard spreader in the shot charge, thus dividing it into four segments. Brush shells have little or no effect on the pattern of an improved cylinder barrel.

Shot Concentrators, on the other hand, have not been as successful as spreaders. Manufacturers have not yet found any reliable method of concentrating the pattern, other than the choke in the barrel. Various methods will tend to concentrate the shot, but no way has been found to time the breaking up of the charge for a specified distance.

We occasionally hear of a shooter cutting a ring around the wall of the paper case behind the base wad under the shot charge, so that the shot-charge, with the inclosing paper shell walls and wads, will stay together when fired and act more or less as a solid projectile. *This is an exceedingly dangerous practice.* It sets up a very high breech pressure as the solid mass is forced through the cone, and the

inclosed shot charge will have difficulty in passing through the choke, and may also cause the barrel to burst at the muzzle.

Single Ball Loads. Single, round, lead balls are sometimes used in shotguns for the shooting of deer and other large animals. For safety, the ball should always be small enough to pass through the choke, and there should be no top wad over the ball, the paper shell being merely crimped down on the sides of the ball. The accuracy with single round ball loads is not very good. Usually at 60 yards ten consecutive shots will not all strike on a target four feet square. There are exceptions which do a little better, depending on the gun and the type of the load. But generally speaking round lead balls in shotguns are not accurate enough to surely hit a deer in the body at beyond about thirty yards.

Rifled Slug Loads. The accuracy of the conical rifled slug bullets, recently introduced in the United States, is much better than with round lead balls, and such loads are more reliable for deer shooting at short distances. In cylinder bore guns these slugs will usually group in approximately three to five inches at fifty yards, and in about ten to fifteen inches at a hundred yards. They are not quite so accurate in a choked gun, but the difference is slight. There is, however, a certain amount of difficulty with the accuracy of aim which increases the actual dispersion. With the rather crude method of aiming the shotgun the alinement frequently varies as much as five inches at 50 yards, even when pains are taken in aiming, and this radius must be added to the radius of the group.

Extreme Range of Shot

Because of safety reasons the extreme range of a shotgun should be known. The distance to which the pellets will range depends on the size, that is the weight of the pellet, and on the angle of elevation of the gun. As with the rifle, the extreme range occurs when the barrel is elevated at an angle of about thirty degrees. At this angle large buckshot, round balls, and rifled slugs, when fired at a muzzle velocity of 1300 f.s., which is about the average, should be assumed to have a range of about 900 to 1,000 yards and to be more or less dangerous at these distances.

Ordinary small sized shot, No. 2 and smaller, do not have anything like this extreme range. With the shotgun loaded with No. 4 or No. 6 shot, and the barrel held horizontal about five feet above the ground, the nearest pellets will strike the earth at about 100 yards, and those pellets of No. 4 shot which range the furthest will strike the ground at about 250 yards. With the barrel elevated to thirty degrees pellets of No. 4 shot may range as far as 300 yards. Therefore, on a trap range there should be a controlled safety zone of 300 yards ahead of the firing point. This might be reduced to 200

yards for a skeet range because the small No. 9 shot will not range so far. Still we do not know when some individual may shoot duck loads at skeet, and it is better to play safe and have a 300 yard safety zone.

When bird shot is fired straight up, it does not fall with much greater force than a heavy shower of rain. This is because of the resistance of the air in retarding the velocity of vertically falling bodies. But this is not true of shot falling at an angle of thirty degrees or less, where some of the energy imparted by the powder charge remains, so that such shot might bruise the body or destroy eyesight.

Comparison of Gauges

So far as ballistic efficiency alone is considered, the 12 gauge is the most efficient bore. It is granted that a 10 gauge could be made more effective than a 12 gauge, but only at a prohibitive weight when we consider the shotgun as a weapon for shooting birds on the wing.

But so long as we use the shotgun for the above purpose, lightness and general handiness will be weighed against ultimate ballistic efficiency. How much do we lose ballistically in selecting a 16 or 20 gauge gun instead of a 12 gauge?

The mean velocity over 40 yards, and the percentage of pellets inclosed in a 30 inch circle with various degrees of choke is the same for all three gauges. Ballistically there are but two differences. Normally, 12 gauge shells are loaded with more shot than 16 gauge, and the latter gauge with more than 20 gauge. Thus, with a 12 gauge there are more pellets per load, the pattern is denser, birds will be struck with a greater number of pellets, and sufficient pellets to kill will strike the bird at a longer range than with a 16 or 20 bore. Then, in addition, there is the fact that a 12 gauge gun gives better patterns with the larger sizes of shot than do the smaller bores.

The average factory shell of today is loaded with 1¼ ounces of shot in 12 gauge, 1 ounce in 16 gauge, and ⅞-ounce in 20 gauge. Therefore the number of pellets in each gauge will be:

Gauge	*Wt. of Shot*	*No. 4 shot*	*No. 6 shot*	*No. 8 shot*
12	1¼ oz.	170 pellets	279 pellets	511 pellets
16	1 "	136 "	223 "	409 "
20	⅞ "	119 "	195 "	359 "

Based on the theory that it takes three pellets to kill a bird, and on the theory of probabilities, we might by tedious calculation arrive at the distances at which each gauge and size of shot would throw a pattern dense enough to theoretically kill each of the species of birds represented by so many square inches of body surface. But

there would be too many variables in actual practice to make such a computation of much value.

It is common sense that with No. 8 shot, a pattern dense enough to surely kill quail will be obtained at a longer distance with 511 pellets in a 12 gauge gun than with 359 pellets in a 20 gauge. For an answer as to the distances at which the various gauges will be effective it is thought best to rely on the collated experience of our older game shots.

The concensus of opinion is that when the choke and size of shot are the same, the effective killing distance of the 16 gauge is about three to four yards less than that of the 12 gauge, and the 20 gauge is about three to four yards less than the 16 gauge.

At one time Major Charles Askins made an effort to determine the maximum range of duck guns from 10 to 20 gauge, as determined by the pattern, using the same size shot throughout. He says: "I shot at the profile of a duck reduced in size to what was supposed to be the naked body of the bird. When the gun failed to put three pellets of shot into this profile it was said to have been "stopped." Several trials were given when a gun began to reach its maximum range, so as to obviate flukes. The shells were the best shells obtainable at the time, all loaded with No. 6 Lubaloy shot. All guns were full choked and were started at 40 yards, then moved back a step at a time until stopped. The summary follows:

20	gauge,	1	ounce	shot,	Stopped	at	45	yards.
16	"	1⅛	"	"	"	"	48	"
12	"	1⅛	"	"	"	"	50	"
12	"	1¼	"	"	"	"	54	"
12	"	1⅜	"	"	"	"	58	"
10	"	1⅝	"	"	"	"	65	"

"At the time of this trial the Winchester Magnum (Heavy Duck Gun) with 3-inch cases (12 gauge) and 1⅝ ounces of shot had not yet appeared. But, shooting this gun afterwards and finding that it would pattern over 80 per cent of its big charge, I never had any doubt but the gun would kill as far as the 10 bore with a similar load—65 yards."

CHAPTER XI

Care and Storage of Arms and Ammunition

SMALL arms are constructed chiefly of steel and wood. Steel will rust and wood will swell and warp in the presence of moisture. The effect of rust is to eat away the steel, therefore a rusted surface can never be returned to its original condition without removing the standing surfaces between the rust pits, which would alter the dimensions. Wood that has warped cannot usually be restored to its original shape and dimensions. Under certain conditions rusting, swelling, and warping can occur in a very short time, sometimes in a few hours. The surface and interior of a small arm may become wet from rain or snow, from immersion in water, or from moisture in the air. Certain substances (particularly salts) in contact with steel will hasten and increase the deposit of moisture. Humidity is greatest close to large bodies of water and in the tropics, but even in dry desert regions humidity increases greatly at nightfall. Only at extremely low temperatures is moisture absent from the air, but very cold steel and glass brought into a warm house will become heavily saturated with water at once from condensation. All of this also pertains to tools and instruments, and indicates the cleaning and care that is necessary.

The use of non-corrosive ammunition does not prevent rust in the bore. There may be nothing in the fouling of such ammunition which would of itself cause rust, but there is also nothing that will prevent rust from moisture, except perhaps to a small extent when the cartridge is loaded with a lubricated lead bullet. But non-corrosive ammunition has considerably simplified the effective cleaning of small arms.

If a steel surface be made clean and dry, and then be coated with a rust inhibiting grease, it will not rust. The preventing of swelling and warping of wood is not so simple. The best that can be done is to keep the pores of the wood filled with an oil such as linseed oil, and insure dry storage so far as possible. Preservation depends upon proper care at the right time, not on extent or frequency of cleaning. The writer has seen small arms that have been properly cleaned and

then stored for ten years and more in extremely damp tropical climates. When the wooden chests were opened the arms were in perfect condition.

Cleaning and care involves a certain amount of labor. Often this labor comes at the end of the day when one is tired. It should, therefore, be reduced to the easiest, quickest, and cheapest method that

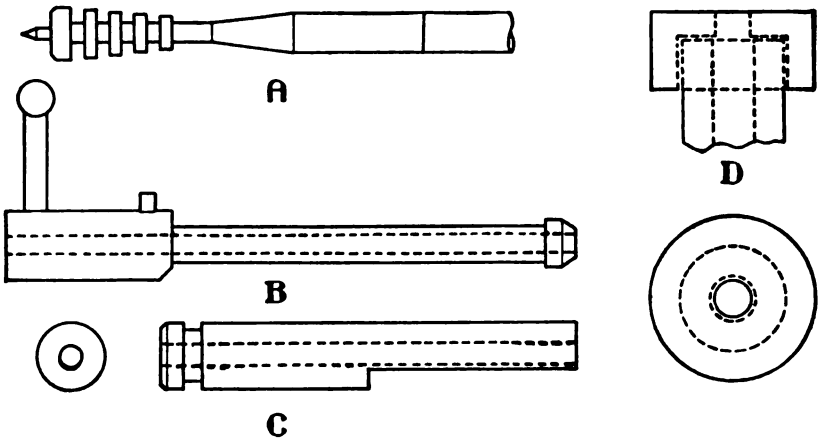


FIGURE 53

A. The most convenient form of tip to hold the flannel patch on the cleaning rod. The center of the patch is punctured with the sharp tit, which holds the patch on the tip while it is being inserted in the chamber or bore.

B. A cleaning bolt for a center-fire, bolt action rifle. The bolt handle turns down and locks over the bridge of the receiver, and the tapered tip fits against the shoulder in the chamber. Rifle is then cleaned through the bore which prevents wear of bullet seat or leade by the cleaning rod.

C. Cleaning bolt for Winchester Model 52 and Remington Model 37 match rifles. The bolt is inserted in place of the regular bolt when cleaning. The groove at the end facilitates the removal of the bolt.

D. Muzzle guard of brass fitting over the muzzle of a barrel that has to be cleaned from the muzzle. The cleaning rod runs through the small hole in the guard which prevents all muzzle wear.

is entirely effective. Such are the methods given below. Other methods may or may not be effective.

Tools and Materials Required

Cleaning Rods. For rifles and pistols the ordinary brass cleaning rod is not very satisfactory. It bends and rubs the bore. When two metals are in moving contact the softer will carry grit and abrasives and wear the harder. The best rifle and revolver rods are made of stainless steel, which is straight and has enough spring to remain straight. A one-piece rod is best, although jointed rods are indicated

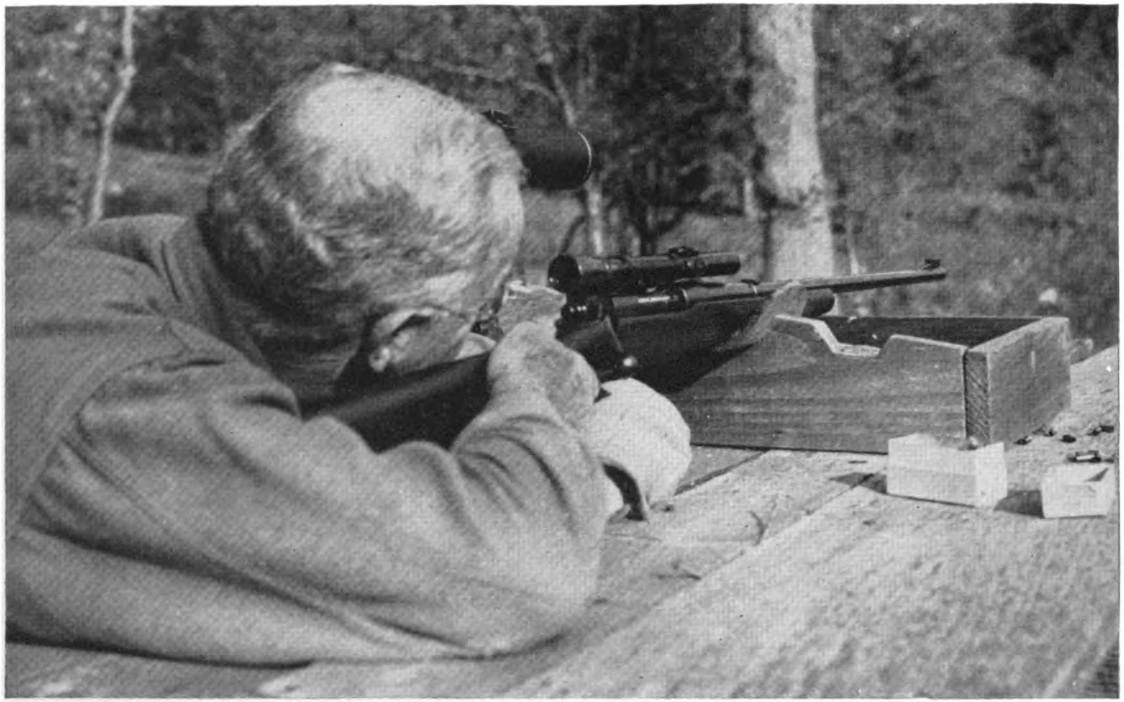


FIGURE 47A

Showing the bench rest firing position. The box used for the forearm rest is weighted down with a rock, and can thus be pushed over the bench top to any location desired so as to conform to the rifle and the steady position of the firer. The forearm is rested on a half-inch pad of sponge rubber procurable at most dime stores. The three notches at different heights accommodate themselves to the firer and his rifle so that the sights point approximately on the target. The arms are folded as shown. The toe of the butt-plate rests between the third and little fingers of the left hand, those fingers also resting on the bench top, or if the bench top is not sufficiently high to bring the line of aim on the target, then on a thin block of wood placed on the bench top. The forearm rest box is pushed to the right or left to secure suitable windage direction. The right pectoral muscle, and the left side of the chest rest against the edges of the cut-out portion of the bench top. It is usually best not to let the left pectoral region touch the bench as this may introduce a heart pulsation into the holding.

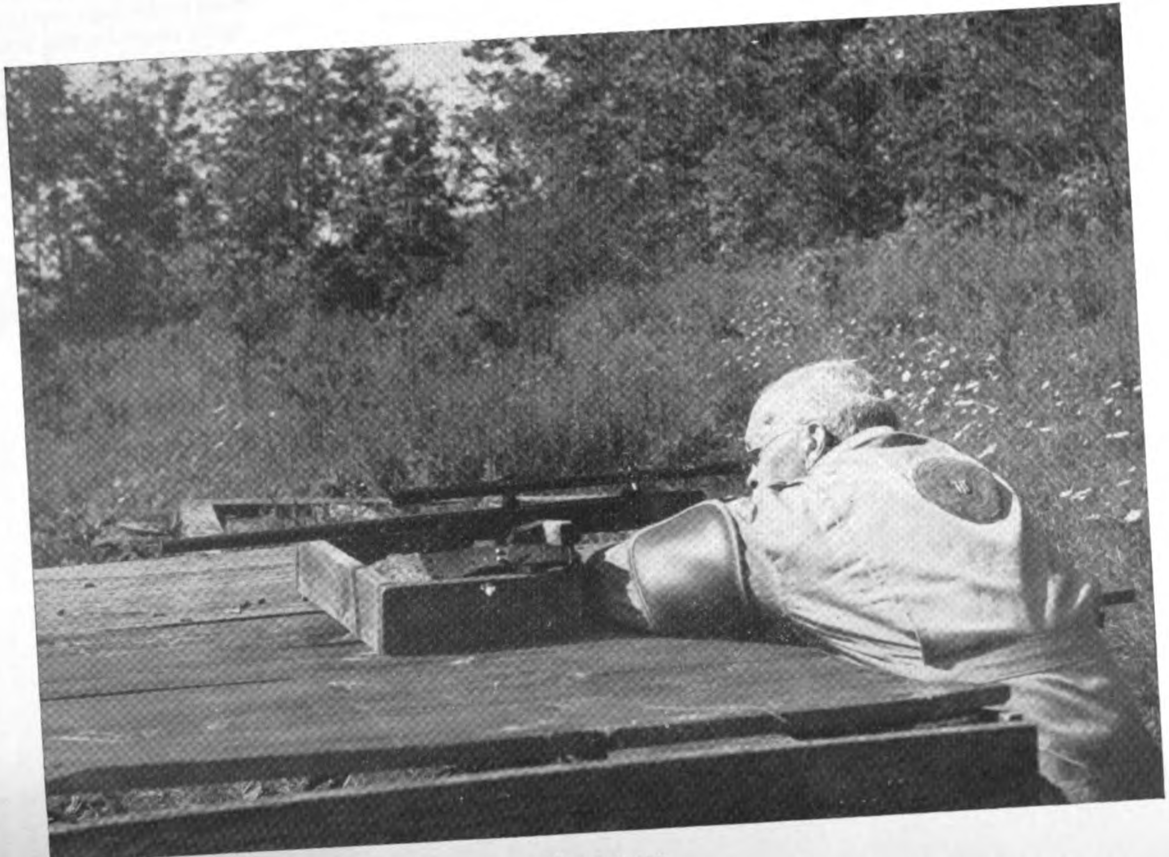


FIGURE 47B

Left side view of bench rest firing position. The spotting scope has been removed for clear view.

for field service because they can be packed in smaller space. The rod should be about .203-inch in diameter for .22 and .25 caliber weapons, and .250-inch in diameter for larger bores, and should be provided with a strong, rotating handle. The assembled rod should be at least six inches longer than the combined length of barrel and receiver.

There should be two tips. One to be threaded so that a brass wire bristle brush can be screwed on it. The other is for use with the flannel cleaning patches, and the best shape for this tip, considering effectiveness, safety, and ease of operation, is as shown in Figure 53. The flannel patch is centered and pushed onto the sharp tit, and this holds the patch on the tip while the rod is entered and pushed through the chamber into the bore, and insures the tip centering the patch. The tip should be of a diameter proportionate to the bore of the weapon and the thickness of the flannel patches. Such tips, by their convenience, easily save one minute in the amount of time required for normal cleaning as compared with all other forms. Such rods are at present manufactured by the firm of Belding and Mull, Philipsburg, Penna.

For shotguns of 20 gauge and larger the ordinary commercial wooden rod is entirely satisfactory. It should also have two tips, one for patches and the other for a brass brush or Tomlinson cleaner. For 410 bore and 28 gauge shotguns it is best to use the rifle rod as above with suitable size tip.

Brass Brushes, in calibers from .22 to .50 are sold by all dealers in firearms. For shotguns of 20 gauge and larger the Tomlinson cleaner, fitted with replaceable pads of brass wire gauze, is best. Brushes and pads will usually last for from ten to twenty-five cleanings. Do not reverse them in the bore, which ruins them very quickly. Push them straight through the bore and out the muzzle; then pull them straight back and out the chamber. They are easily cleaned in boiling water. *Under no circumstances should a steel wire brush be used, as sooner or later it will scratch the bore.*

Cleaning Bolts and Muzzle Guards, as shown in Figure 53, are not absolutely essential except for .22 caliber match rifles. The cleaning rod in use is liable to wear the bullet seat and leade, or when the rifle has to be cleaned from the muzzle it may wear and "bell muzzle" the bore at that end. Wear at the bullet seat and leade results in gradual decrease in accuracy, and that at the muzzle results in progressive change in the zero and sighting of the rifle, and also there may be a loss in accuracy. Ordinarily this wear is almost inconsequential where rifles are used and cleaned only a few times a year. But a .22 caliber match rifle in continual use often has to be cleaned several hundred times a year, and the prevention of cleaning wear becomes more important.

A cleaning bolt consists of a bolt of any metal which fits in the receiver in place of the regular bolt, and extends into the chamber up to the neck thereof. It is bored from front to rear of the same diameter as the bore of the rifle, and is placed in the receiver before cleaning. The rod carrying the flannel patch or brass brush is entered at the rear end, and is operated through the cleaning bolt, by which it is guided so that it does not rub the bore just ahead of the chamber. Note, however, that when it is used the chamber is not automatically cleaned, and it is still necessary to remove the bolt and, using cleaning patches on the rod, by running the rod only an inch or so into the bore, to clean and oil the chamber.

For .22 caliber rim fire rifles, suitable cleaning bolts can be made from hardwood. Their forward end does not enter the chamber, but merely abutts against the breech of the barrel, so that the chamber is automatically cleaned when the bore is cleaned.

A muzzle guard, for use with a rifle which has to be cleaned from the muzzle, consists of a brass cap which is made to slip over the muzzle and is bored centrally with a hole just large enough to admit the cleaning rod. The guard is slipped over the rod, a flannel patch is then placed on the tip and the tip entered an inch into the muzzle. The guard is then slipped down over the muzzle, and the bore can then be swabbed as vigorously as desired without the rod rubbing the muzzle.

Cleaning Patches. Do not use any available old rags for cleaning patches. Sooner or later the rod will puncture such a patch, the patch will get stuck in the bore and it will be difficult to remove it without injuring the bore. Old underwear contains salt from perspiration. Cleaning patches should be made from medium weight canton flannel which has been washed (put through the laundry) to make it more absorbent. From this, the patches should be cut out in the form of squares, or punched out with a round punch. They should be about 7/8ths to 1¾ inches in diameter, depending on the weight of the flannel, the diameter of the bore, and the diameter of the tip on the rod. The size is very important and should be such that when placed on the rod it will take a pressure of about five pounds on the rod handle to push the patch down through a clean bore. If the patch is too tight the rod may puncture it, or it may stick in the bore, and then there will be plenty of trouble. If too small, it will not clean the bore well. Cut cleaning patches are sold by dealers in firearms, or one may cut his own. In buying cut patches be sure they are correct weight and diameter for the rod and bore.

Note that when water is used for cleaning, when the bore is about half dry it is sticky inside, and at this juncture the patch being used should be trimmed a little smaller or it may stick in the bore.

Wiping Cloths. Two canton flannel wiping cloths should be pro-

vided, each about a foot square. One should be dry, to wipe the exterior of the weapon clean. The other should be slightly saturated with oil for the final wiping of the weapon before placing it in the rack. Instead of flannel a piece of chamois skin, also saturated slightly with oil, is fine for this final wiping. After the final wiping, place the weapon in the rack or gun cabinet, handling it by the wood stock only, and do not permit the hands to touch the steel surfaces. Sweaty hands are great promoters of rust.

Cleaning Solution. A cleaning solution or powder solvent is not absolutely essential for cleaning the bore, but it very greatly expedites the removal of fouling and dirt, greatly reducing the time necessary as compared with oil or water. There are a number of cleaning solutions on the market that are entirely satisfactory. The oldest and commonest, "Hoppe's Powder Solvent No. 9," is as satisfactory as any. Or a cleaning solution may be made of sperm oil 1 ounce, amyl acetate 2 ounces, and acetone 2 ounces. Dissolve the oil in the acetate using only as much oil as the acetate will take up. Then add the acetone, a little at a time, with thorough shaking.

Remember that all these powder solvents are cleaners only. They are not good rust preventives, nor have they any effect in dissolving metal fouling. They should not be left in the bore.

Lubricating Oil. A good lubricating oil is necessary for ordinary oiling and lubricating of the breech mechanism. It may also be used as a short time rust preventive in the bore, when the weapon is being used each week. This oil should have a good body, that is it should not be very thin like some "sewing machine" oils, so it will stay in place and not run off. There are many satisfactory oils on the market. Ordinary sperm oil has been used by the Ordnance Department of the Army for many years. Any of the oils put out by our Arms Companies are satisfactory.

The usual oils will congeal, become solid, and often make the breech mechanism inoperative at low temperatures in winter. Transformer oil is usually satisfactory down to -10°F, but is not a good rust preventive. In extremely cold weather every trace of oil should be removed from the mechanism. Finely powdered graphite may then be used as a lubricant.

Rust Inhibiting Grease. There are many such greases on the market which are good under ordinary conditions. Some of them, however, are so thick that they are tedious to apply and remove. The Ordnance Department of the Army has made a study of rust inhibiting greases over many years, and their specifications require effective protection for many years storage in damp and tropical climates. One grease which passes these specifications, and is thin enough to apply and to remove easily, is manufactured by the Standard Oil Company of Indiana, and is procurable in almost all

sporting goods stores under the trade name of "RIG." It comes in small cans and tubes.

When arms are issued in the Army, and when they are sold in stores they are usually more or less coated, and the bore is filled with rust inhibiting grease. Sometimes this grease is very thick and tenacious. *It must always be removed before the weapon is used.* Particularly if this heavy grease is permitted to remain in the bore, and the weapon be then fired, the bore may be enlarged, or the barrel bulged or even burst wide open. Most of our commercial arms companies attach a tag to each new gun, cautioning the purchaser to remove all heavy grease before firing. This grease can be easiest removed by placing a little gasoline on the cleaning patch or wiping cloth.

Use of the Cleaning Rod

Whenever possible clean the barrel from the breech end, removing the bolt from the rifle, or the barrels from the breech of the shotgun. Place a little board, about six inches square, on the floor, and rest the muzzle of the barrel on this while cleaning the bore.

Center a flannel cleaning patch on the tit of the patch tip of the rod. Enter the patch and rod into the chamber, and push the patch down through the bore until the rod tip touches the board on the floor, then reverse the motion and pull the rod and patch up through the bore until the patch is felt to just enter the chamber, then push down to the muzzle again. In this manner push and pull the rod and patch through the bore five or ten times. This is termed "swabbing the bore." Finally push the rod and patch all the way through the muzzle, then pull the rod back, and the dirty patch will fall off at the muzzle. So far as practical, try to run the rod centrally through the chamber so it will not unduly rub and wear either side.

If the construction of the weapon is such that the bore must be cleaned from the muzzle, provide an empty cartridge case that has been trimmed at the mouth so as to shorten it $1/8$th inch, and fit a tight wood plug inside this case so that the end of the plug comes just flush with the mouth of the case. This is placed in the chamber before cleaning, and the action is then closed. It keeps the cleaning rod from injuring the bolt face, keeps dirt from being pushed down into the mechanism, and the rod and patch can be pushed down to the case and then pulled back in swabbing the bore without the cleaning patch coming off in the chamber. The swabbing then cleans the bore right to the end of the bullet seat, but does not clean the chamber.

Enter the rod and patch from the muzzle, pushing the rod down until it touches the plugged case, then pull it back, thus swabbing the bore. If not using a muzzle guard, hold the fingers at the muzzle,

and guide the rod as it runs through the muzzle, so the rod does not unduly rub and wear the muzzle. The bore having been cleaned, take a very short piece of rod with a slot in it, carrying a flannel patch, working it through the breech mechanism, and clean and oil the chamber. The twisted wire cleaning rods with bristle brush attached, which are furnished for cleaning revolvers, are fine for cleaning the chamber of a rifle, as the flexible wire rod can be bent so it will enter the chamber through the mechanism.

A revolver usually has to be cleaned from the muzzle. Hold a finger over the breech of the bore, to prevent pushing out the patch when swabbing. When cleaning the chambers in the cylinder hold the revolver by the cylinder only, and not by the frame, so as to avoid placing strain on the cylinder hinge. Wipe off all surfaces where the fouling has caused an exterior smudge, and do not neglect the firing pin nose on the hammer, nor the recoil plate.

Normal Bore Cleaning

This is the ordinary cleaning that is necessary when modern American non-corrosive ammunition has been fired in the weapon. Usually it is the only bore cleaning that is necessary, and consists of three operations—loosening the fouling, cleaning out the fouling, and protecting with grease—which are numbered below for clarity. It is strongly advised that the bore be cleaned in this manner *not later than the evening of the day on which the weapon was fired,* because the amount of moisture in the air commonly increases greatly at nightfall, and there is always danger that the bore may rust overnight from the moisture it absorbs from the night air. Note that there are cases where this normal cleaning should be varied, these being given below.

1. **Loosening the Fouling.** Swab the bore thoroughly with a flannel patch saturated with the cleaning solution or powder solvent. If this is not available, swab with four or five patches saturated with lubricating oil or water, or soapy water. If using water take precaution that no water gets in the mechanism. Note that oil or water take very much more swabbing and time to loosen up the powder and primer fouling than does a good powder solvent.

2. **Cleaning Out the Fouling.** Wipe the rod off and then swab the bore with four to eight clean, dry, flannel patches, until finally a patch comes out fairly clean and dry, indicating that the bore is clean. With certain types of rifle powder, which contain graphite, the patches will never come out clean but will be stained dark gray as though rubbed with a lead pencil. Disregard this stain. If the bore has been swabbed with water in Operation 1 it will be sticky when half dry, and at this stage the flannel patch should be trimmed a trifle smaller to avoid danger of its getting stuck in the bore.

Now hold first the muzzle, and then the breech up to the light and examine the surface of the bore to see that it is perfectly clean and bright from breech to muzzle. If it is—well and good. But if long streaks are seen on the surface of the bore, indicating remaining powder fouling or leading, then more energetic loosening up of this fouling is necessary. In that case, after swabbing with the powder solvent as in Operation 1, and while the bore is still wet, screw a brass wire bristle brush (or Tomlinson cleaner for a shotgun) on the brush, and run it back and forth through the bore five to ten times, to loosen up this tenacious fouling or leading. Then swab again with powder solvent, and afterwards continue with this Operation 2, and dry patches.

After three or four cleanings one will learn if the use of the brass brush is necessary with the ammunition he is using. If so, then the use of the brass brush should be incorporated in Operation 1. Ordinarily it is not necessary with .22 rim fire ammunition, or with modern commercial revolver and pistol cartridges, but is usually necessary with Government rifle ammunition and shotgun shells.

3. **Protecting the bore.** The bore being clean and dry, saturate a flannel patch with rust inhibiting grease and sop the bore thoroughly with it. See that the bore be coated with the grease. Push the patch out the muzzle, withdraw the rod, pick up that patch and wipe the outside of the muzzle with it. If the weapon is to be shot again within a week, lubricating oil instead of grease may be used to protect the bore, but for longer periods the grease should be used.

This completes the ordinary normal cleaning of the bore. The weapon should then be wiped off with a dry cloth, and then the metal parts, and the interior of the mechanism that can be easily reached should be wiped with the oily cloth. Then, handling the weapon by its wood stock so as not to get finger marks on the oiled steel surface, the weapon should be placed in a rack or gun cabinet. It is best placed in the rack or cabinet muzzle down, so that grease will not drain into the breech mechanism. Most gun cases are liable to absorb moisture, and should only be used when travelling. In the rack or cabinet the gun should be supported only on oiled wood. There is always some danger that these green felt coverings to gun racks may also absorb moisture and rust the weapon where it touches.

Occasionally, and always after it has become wet, or has been handled with sweating hands, the stock should be given a rubbing with oil or wax. Place a few drops of boiled linseed oil in the palm of the hand, rub both palms together, and then rub the stock and forearm vigorously until they have become slightly warm. On a highly polished stock, use carnauba wax, or liquid wax furniture or floor polish, instead of linseed oil. Take reasonable care not to get

linseed oil or wax on the metal surfaces, as it will harden thereon and require turpentine to remove it easily.

Occasionally, when needed, the breech mechanism should be cleaned. With a bolt action rifle, the mechanism of which can be dismounted entirely with tools, it is easy to wipe every part with the dry and then the oily cloth. A stick will help to get the cloth to the parts of the mechanism of other weapons that are not so conveniently accessible. Fine double barrel shotgun locks should occasionally be lubricated lightly with watchmaker's oil. But it is a mistake to squirt too much oil on a lock or breech mechanism. Usually, wiping with the oily cloth is all the lubrication that is necessary. *Particularly this is all the lubrication that the lock mechanism and firing pin or a .22 caliber match rifle should have.*

Before shooting again, be sure to wipe all grease from the bore and chamber. This can be usually done by swabbing with one or more dry, clean patches. With very heavy grease, the first patch may have to be saturated in gasoline. Do not leave gasoline in the bore. As stated before, grease in the bore and chamber causes high breech pressure, and in addition is a mechanical obstruction to the bullet. The bore and chamber may be enlarged, the barrel may be bulged, or the barrel may even burst. This precaution is very important.

A thin coating of light oil in the bore and chamber will do no harm, but with a rifle or pistol is almost certain to cause the first shot to fly rather wide of the mark. Nevertheless, when hunting on a rainy day, or when shooting ducks, it may be a good thing to have the bore just wiped out with a slightly oily patch as a protection from rust. Ordinarily the bore should be clean and dry for the first shot.

Exceptions and Precautions

.22 Caliber Rim Fire Ammunition. Those varieties of this ammunition that are non-corrosive, and in addition that are loaded with *lubricated lead bullets,* deposit a fouling in the bore that is a fair rust preventive. Except in an exceedingly damp climate the bore will not rust if left uncleaned for many weeks. Cleaning is, therefore, not nearly so important in this case. But for the very finest accuracy it is best to clean the bore daily, and always before storing the rifle or pistol away for very long periods. In the factory, where conditions are ideal, rifles have been shot with non-corrosive .22 Long Rifle cartridges loaded with lubricated lead bullets for a half a million rounds without any cleaning whatever, and afterwards have been found to be in perfect condition.

Some super-accurate .22 Long Rifle match cartridges are loaded with Lesmok powder, and are not non-corrosive. When these are used the bore should be thoroughly cleaned not later than the

evening of the day when fired, and if placing the rifle away for any length of time this cleaning should be with water.

Potassium Chlorate Primers. Before the introduction of the present commercial non-corrosive ammunition almost all cartridges and shotgun shells were primed with potassium chlorate primers. Some Government rifle ammunition, particularly that of .30-06 caliber, is still primed with these primers because, better than any other, they will stand long tropical storage. If the carton in which the cartridges are packed is not plainly marked "Non-corrosive," "Stainless," or "Kleanbore," it is best to assume that the cartridges are primed with a chlorate primer and to proceed to clean accordingly.

The product of combustion of a potassium chlorate primer is a salt known as potassium chloride, very similar to sodium chloride or table salt. On firing, this salt is deposited all over the surface of the bore, and it at once begins to absorb moisture from the air, and the bore starts to rust very quickly. Particularly, if the fouling is left in the bore overnight rust will almost certainly start before morning. *Potassium chloride will not dissolve in any powder solvent or oil.* Cleaning with these is not safe. The only liquid which will completely dissolve and remove potassium chloride is water or aqueous solutions such as ammonia. Water is as good as anything and costs nothing. Therefore to clean, in Operation 1 above, swab with several patches saturated with water, instead of powder solvent or oil. Most of the powders used when potassium chlorate primers were being loaded gave a rather sticky, tenacious fouling, and a brass wire bristle brush was almost necessary to loosen it up. Therefore it is best and easiest to swab with water, then use the brass brush, then swab with water again, and finally dry and clean with dry patches, and protect the bore with grease.

When potassium chlorate primers are used in very small cartridges such as the .25-20, the chloride fouling is so little diluted by the small amount of powder fouling that rusting takes place at once, and the writer has found no way of preserving the bore with such a combination. Even cleaning the bore immediately after firing will not prevent pitting.

Leaded Barrels. Almost always a few passages of a brass wire bristle brush or a Tomlinson cleaner will remove all lead from the bores of .22 caliber rifles and shotguns. In obstinate cases swab the bore thickly with mercurial ointment (procurable in any drugstore), and let it stand a few days. Then use the brass brush again.

Before the introduction of non-corrosive ammunition the bores of many .22 caliber rifles, if not habitually cleaned promptly and thoroughly, leaded and fouled badly. The bore appeared in very bad condition, and apparently the shooter could not get it clean. The novice said that the bore was "leaded," and he would have to

take it to a gunsmith to have the lead removed. The gunsmith could do nothing. The bore was simply ruined, and could not be restored. The only remedy was a new barrel. We do not often now see barrels in such horrible condition, thanks to the non-corrosive ammunition.

Precautions: So far as possible keep oil and grease from ivory sights and soft rubber buttplates. Gun oil and grease rubbed on the stock will eventually turn it black and destroy the figure of the wood—use linseed oil or wax. Canvas, flannel, sheepskin, and leather cases and holsters are for carrying and transporting weapons. Weapons should not be habitually kept in them for they are liable to absorb moisture and cause rust. A leather gunsling, particularly when made of some leathers, may do the same thing. Gun wicks, or anything stuck in the muzzle of a gun are particularly bad.

Storage of Small Arms

If the weapon is to be stored for a long period, or if it is to be shipped overseas, clean it thoroughly as above, then if possible, several days later wipe the bore clean and dry, and swab again with a very heavy coat of rust inhibiting grease, and fill the muzzle with some of the grease. Wipe the exterior dry and clean, and then paint heavily with rust inhibiting grease. Without touching the metal, place the weapon in a chest where it is secured by an oiled wood socket at the muzzle, and oiled wood clamps or braces at the breech and butt. Then screw the lid of the chest down tight.

It is not a bad plan to place a large piece of pure gum camphor in a little wood box with small holes bored through it, and nail this box in the corner of the arms chest. As the camphor evaporates it deposits camphor oil over the weapon, and this is a good rust preventive. Also it discourages insects. The writer has had two rifles ruined by ants which nested in a storage chest. For the same reasons, a lump of camphor is a good thing to keep in a gun cabinet. So far as possible, guns should be stored where it is dry and where the temperature is fairly equitable—not in a damp cellar or an attic that is extremely hot in summer.

Recapitulation. The above notes on cleaning and care may seem rather complicated. They were not intended to be, but rather to cover every case that might occur. Cleaning and care is really very simple. With ninety five percent of the modern arms and ammunition being used today it is only necessary to swab the bore with powder solvent, dry and clean with a few flannel patches, then sop with a patch saturated with grease, and finally wipe the weapon off with an oily rag. Where the implements and materials are conveniently at hand, this does not take over five minutes. The weapon will then stand almost indefinitely with no deterioration.

Care and Storage of Ammunition

Loaded ammunition, powder, primers, and metallic components should be stored in general as one would store books—that is, where it is neither excessively damp nor hot. Avoid damp cellars, or attics that get exceedingly hot in summer. Keep powder canister tops screwed down tight.

For long periods of storage the writer has found it best to remove cartridges and shells from the pasteboard cartons in which they are regularly packed, and place them in wooden boxes, or in cigar boxes from which the interior paper has been removed. The pasteboard cartons sometimes absorb dampness and corrode the brass or copper cases. Modern cartridges do not get dangerous with age. If anything, they tend to weaken slightly.

Metal Fouling

This subject has been left to the last because it is so seldom encountered in these days of modern improved ammunition. Prior to about 1925 the bullets used in cartridges for high intensity rifles were jacketed with cupro-nickel, and metal fouling was then a serious problem. Today, when practically all of our rifle bullets are jacketed with gilding metal or copper, it has practically disappeared. Nevertheless the ballistician should understand it, because he may have occasion to use cupro-nickel jacketed bullets for experimental purposes, or he may run up against a case of true metal fouling in a shooter's rifle and wish to remove it.

Modern rifle ammunition loaded with bullets jacketed with gilding metal or copper does not deposit true metal fouling, but does very slightly plate the bore of the rifle with copper. If the bore of a high power rifle that has been shot at least a few times be examined from the muzzle in a good light, this copper plating can be seen. The surface of the bore has a decided copper color. This plating is extremely thin, and moreover it does not seem to accumulate with repeated firing or get any thicker. The writer has endeavored to measure its thickness but has been unable to do so. It cannot be measured with the Springfield Armory Star Gauge which will record to .0001-inch. There has never been any conclusive evidence that this copper plating did any harm at all. It has no effect on accuracy, and there is some reason to think that it may slightly delay corrosion and erosion. It need not be removed, and should be disregarded. However, if anyone desires to remove it, this can easily be done with the standard ammonia metal fouling solution as described below.

True metal fouling results chiefly from firing cupro-nickel jacketed bullets at muzzle velocities of about 2200 f.s. and over, al-

though very isolated cases have occurred with soft copper jackets at extremely high velocities. The higher the velocity and the rougher the bore, the faster will this fouling accumulate. Extremely smooth bores are not entirely immune. In the .30-06 Springfield Model 1903 rifle when used with the old Ball Cartridge, Caliber .30, Model 1906 (150 grain cupro-nickel jacketed bullet at M.V. 2700 f.s.) it could often be seen after firing only ten rounds.

This true metal fouling is plainly apparent in the bore. If the bore be cleaned and dried, and then viewed from the muzzle in a good light, the streaks, flakes, and lumps of the fouling can be seen adhering to the bore for some ten inches down from the muzzle. It looks like smears of lead, usually on top of the lands, but sometimes in the grooves as well. It appears to have a thickness about equal to the height of the lands, or half as much; that is about .002 to .004-inch thick.

Metal fouling in its first light stages does not seem to interfere appreciably with fine accuracy. At least, in the days when we used cupro-nickel jacketed bullets in normal, or at least fairly smooth barrels, we usually got first rate scores for perhaps the first forty shots. It was the practice then among our best marksmen, when shooting all day in competitions, to clean their rifles free from metal fouling at noon, and again after the day's shooting. But as metal fouling accumulates the accuracy falls off to a very noticeable degree. When this fouling is removed the original accuracy is restored, provided that it is removed before rusting takes place. Corrosion starts very quickly, perhaps in a day, under the metal fouling.

None of the so called "Powder Solvents" have any effect whatever on metal fouling. A brass brush will sometimes remove a little of it, but not all of it, and is not effective. Possibly it could be removed by swabbing for hours with a strong solution of ammonia, but no one would attempt the job more than once.

There is but one effective method of removing metal fouling, chemically—by the use of the standard metal fouling solution. This will completely remove it in ninety-five percent of the cases in about half an hour, and in the other five percent a second application will completely remove it. The solution must be used exactly as prescribed. Particularly the solution must be used freshly mixed, although freshly mixed solution may be poured at once into a bottle, very tightly corked, and kept in a cold place for several weeks. It must not be permitted to evaporate on steel or it will rust it in a few minutes. It will burn and discolor wood stocks. The barrel must be permitted to return to air temperature before it is used—that is if it be poured into a hot barrel it will completely ruin the bore instantly. But when used exactly as described it is entirely safe and thoroughly effective.

The Standard Metal Fouling Solution consists of:

Ammonia persulphate	1 ounce.
Ammonia carbonate	200 grains.
Water (cold)	4 ounces.
Stronger ammonia containing 26 to 28% ammonia gas	6 ounces.

Druggists do not usually carry these materials, and they must be obtained from large chemical houses. All the ingredients evaporate very quickly and lose strength unless kept tightly corked. Be sure that the dealer supplies the ammonia carbonate in a tightly corked, wide mouth bottle, and does not merely wrap it in paper as is sometimes done.

To prepare the solution use a glass graduate of 16 ounce capacity. Powder the first two ingredients with a mortar and pestle, or place them in a clean bag and pound with a hammer. Place the powder in the graduate and add the water. Stir with a glass rod until the powder is dissolved, then add the stronger ammonia. The above amount is sufficient to clean about six .30 caliber barrels. If not going to use all the solution at once, pour it into a quart bottle that has a rubber cork that can be clamped down tight with a patent clamp, and keep it in a refrigerator. Do not permit the solution to remain in the graduate exposed to the air for more than five minutes. Ordinarily one should have his rifles already prepared, and as soon as the solution is mixed pour it at once into the barrels.

To prepare the rifle, remove the bolt and cork up the chamber with a tightly fitting rubber cork—the solution will burn ordinary corks. Then slip a section of rubber hose about 3 inches long over the muzzle. The hose should be of a size that will fit water-tight over the muzzle, it is to prevent the solution evaporating on the steel muzzle and rusting that. Also wrap a large rag or towel around the upper end of the barrel and lower part of the rubber tube to prevent accidental spilling of the solution on the outside of the barrel or on the wood stock or forearm. Then stand the rifle, muzzle up, in a firm rack where there is no danger of its falling over. The barrel must be cool—air temperature. Under no circumstances attempt to dope the barrel when it is hot from firing.

Now carefully pour the freshly mixed solution from the graduate or bottle into the bore of the rifle until it rises in the rubber tube so as to cover the muzzle of the barrel at least an inch. Let the solution remain in the bore at least fifteen minutes, never more than half an hour. Gradually it will acquire a deep blue color. After fifteen or twenty minutes reverse the rifle, pour the used solution out, and discard it as it is now worthless. Keeping the rifle reversed, that is muzzle down, remove the rubber tube from the muzzle and, inserting the cleaning rod from below, muzzle still down, push the

rubber cork out of the chamber and catch it with the fingers as it comes out, so no ammonia will get in the breech mechanism. Wipe the rod off, place a dry flannel patch on it, insert it in the chamber and push it through the bore to force out any ammonia that might remain on the surface of the bore. Wipe off the outside of the muzzle. Then immediately swab the bore with several patches wet with water, dry, and grease the bore.

But just before greasing the bore, examine it. It should be perfectly clean and free from all metal fouling. But in the very rare case that some fouling remains, run a brass wire bristle brush through the bore several times (to roughen up the surface of the remaining fouling) and give the bore another dose of the solution.

When the old Caliber .30. M/1906 ammunition was in regular use in the Army, this cleaning with the standard metal fouling solution was prescribed as the standard method of cleaning. In England the solution is known as the "Kings-Norton Solution," and in the days of cupro-nickel jacketed bullets British gun-makers used to treat every rifle with it after proof firing and targeting, and always before shipping the rifle overseas. Even today it is the only absolutely perfect method of thoroughly cleaning a high power rifle. But with the present non-corrosive ammunition and gilding metal or copper jacketed bullets it is entirely unnecessary. Note that some gilding metal jacketed bullets are lightly tin plated, but the copper color can be seen by scratching through the tin. Steel jacketed bullets can be told by applying a magnet. Cleaning after using steel jacketed bullets need be no different than after using gilding metal jacketed bullets.

In this chapter the writer has given the impression that lumpy metal fouling is very seldom present when gilding metal jacketed bullets are used. This is not strictly true when muzzle velocities above about 3500 f.s. pertain. Recently there have been reported a few cases of such fouling in the ultra high velocity .22 caliber varmint rifles such as the .220 Swift and the .22 Varminter. Apparently it occurs with some bullets (i.e., some jacket material) and not with others. The later lots of 8-S bullets produced just before the war were lightly cadmium plated in an effort to avoid this. It was also very apparent that rapid firing and consequent heating of the barrel was a contributing cause.

If much firing was done with a barrel after it had been metal fouled, then when the fouling was removed the bore would be found to be pitted, or perhaps small indentations had been pressed into the surface of the bore where the lumps or smears of metal fouling had been. Such a roughened bore almost always permanently lost much of its gilt edge accuracy.

The writer must here emphasize that such occurrences were rare.

The great majority of shooters using such rifles never encountered anything of the kind.

It would seem that a post-war investigation of jacket material for ultra high velocity bullets is in order. An alloy may be found for jackets that will not be open to this objection, or the cure may be found in the working of the alloy in the mill, and cadmium plating also seems to offer some measure of immunity.

Also such rifles should not be fired fast or extensively enough to unduly heat the barrel. In accuracy tests five-shot groups instead of ten-shot groups had best be the rule because of the lessened heat. And there should be frequent cleaning, possibly after each twenty or thirty rounds, so that any metal fouling can be quickly seen. If present the bore should be doped with the ammonia metal fouling solution. Bullets designed for velocities around 2600 f.s. (.22 Hornet bullets) should not be loaded in such ultra high velocity cartridges. If these precautions be observed there will be little or no danger of injuring a gilt edge barrel.

CHAPTER XII

Hand Loading Ammunition

REFERENCE has been made throughout this work to special loads, cartridges, powders, and bullets which are not regularly furnished or assembled by the leading cartridge manufacturers. Also to experiments and improvements that can be realized only with special ammunition.

It may be a surprise to some beginners to learn that hand-loading ammunition is entirely practical. Likewise it may be news to others that this process is not at all complicated or unsafe, and that anyone can readily master it.

One cannot get very far in the study of Ballistics without resorting to hand loading. Factory cartridges and shells are thoroughly standardized; their performance is well known; and there is no such thing as experimenting with them. Sooner or later the ballistician will desire to develop new loads, new cartridges, or new weapons. Aside from thoroughly learning the capabilities and peculiarities of one's weapon, it is herein that the particular interest in the study and application of Ballistics lies.

Hand loading is no new thing. At the very advent of breech loading arms, in the 1860's, the purchaser of a rifle invariably obtained reloading tools with it, and reloaded all his ammunition as a matter of course as soon as he had fired off his small nucleus of factory cartridges. To this day the arctic traders invariably supply the Eskimo with tools, primers, and lead when they furnish them with rifles and shotguns. Thousands of our sportsmen and shooters are regularly hand loading their cartridges, either for economy or because they want something slightly different from factory loads, but chiefly because they find it so absorbingly interesting. The furnishing of tools, gadgets and components for hand loading has become a very large business in the United States.

The subject cannot be adequately covered in a chapter, and besides there are several thoroughly practical and informative man-

uals dealing with it.* An evening's study of these manuals will make the reader so familiar with the technique that he can go right ahead with perfect safety, and with every assurance of success. Rather it is intended here to give a short summary of the process to show the young ballistician how simple and useful the process is.

Only center fire rifle and pistol cartridges and shotgun shells can be hand loaded or reloaded. It is not possible to do this with rim fire ammunition. There are a number of firms who sell small and convenient tools and accessories for such loading. The arms and ammunition companies use such tools for their hand loading and experiment aside from quantity production of ammunition, and so do all the professional and leading ballisticians. The outlay is not expensive. A complete set of tools of a type which the writer has found to be just as efficient as the most expensive ones, costs (pre-war prices) about $35.00 for the hand loading of one specified cartridge, this including powder measure and scales. The necessary additional dies and fixtures to adapt this tool for the loading of a totally different cartridge cost about $10.25. There are less expensive tools than these, but as a rule, while satisfactory for the ordinary big game hunter, they are not quite capable of the precision work that the ballistician demands.

Primed but otherwise empty cartridge cases and shells, and standard factory bullets can be purchased from the larger ammunition companies or from retail stores who handle these products, or from the makers of reloading tools. Powders of almost all kinds can likewise be purchased from the local powder depots or from dealers. There are small concerns that manufacture special bullets—almost all the special bullets mentioned in this work. Reloading tool makers also list many other components and accessories.

Also there is economy in hand loading, or rather reloading. The brass cartridge case or the paper shot shell is the most costly of the components which comprise the loaded round. Center fire rifle and revolver cases can be reloaded ten to fifty times, and paper shot shells two or three times. At pre-war prices rifle and pistol primers cost 45¢ a hundred and shotgun primers 70¢; jacketed bullets 80¢ to $3.00 depending on size and type, and smokeless powder about $1.60 a pound of 7,000 grains. From this the cost of reloading any cartridge can be figured, and compared with factory prices. Of course real economy results only after the savings have paid for the tool investment, and when the reloader does not charge for his own

* "The Ideal Handbook,"—Lyman Gun Sight Corporation, Middlefield, Conn.
"Belding & Mull Handbook,"—Belding and Mull, Philipsburg, Penna.
"Gunsights, Reloading Tools, Shooting Supplies, Remodeling," Pacific Gun Sight Company, 355 Hayes Street, San Francisco, Calif.
Price fifty cents each postpaid, procurable from the above firms.

labor, which for most is not labor at all but an interesting recreation. It is also possible to mould one's own bullets of lead, and thus economize still further. A bullet mould costs from $5.00 to $7.50, and a lubricating and sizing press (necessary for precision work) $10.00. It is even possible for those with mechanical skill to make their own jacketed bullets, stamping the jackets from sheet gilding metal, casting the cores, and assembling the bullet in special dies, but the outlay in tools is such that there is no economy to the individual.

At first glance it might be thought that the reloading of ammunition was prejudicial to the interests of the cartridge companies. "If a man reloads he buys few factory cartridges." But this is very far from the truth. All but one of our large cartridge manufacturers also make rifles, shotguns, and ammunition components. The average sportsman or periodic hunter buys a rifle and several boxes of ammunition. Thereafter he buys about two boxes (40 to 100 rounds) of factory ammunition every year or two. He uses one box to "sight in" his rifle, and another on his hunting trips. Probably he never buys another rifle unless he experiences some failure, fancied or otherwise, with the weapon he owns, or becomes incited to do so by an article he has read in a sporting magazine.

The reloader is a horse of a different color. Almost invariably he is an enthusiast, often made such by his first experience in reloading. He buys a rifle, 100 or more rounds of factory ammunition (for comparative test and to get the fired cases), a complete outfit of reloading tools, at least a thousand primers, several hundred bullets of several types, and five to ten pounds of powder. Thereafter annually he purchases an equal amount of factory ammunition and components. Usually he exhausts the interesting possibilities of one rifle in a year or so, and he buys another rifle, more tools, factory ammunition, and components, and works with these for several years. Always he has a goal in sight—better accuracy, higher velocity, longer range, better killing power. There are thousands and thousands of men in the United States: reloaders, enthusiastic rifleman, and amateur ballisticians; who are doing just this, and many far more.

Of course all this costs something, but no more than the hobbies of golf and tennis, and nothing like as much as card playing and night clubs. Thus the cartridge manufacturer sells five times as much of his products to such individuals as to the average sportsman, with no detriment whatever to his regular trade with the sportsman.

The experimenters, the reloaders, comprise the bulk of the authors who write for the sporting magazines. All such magazines run an "Arms and Ammunition" column. These columns are replete

with descriptions and details or experiments on the range and in the hunting fields with various arms, ammunition and hand loads. The manufacturers receive far more benefit from these columns than they do from all their paid advertising. If there were no reloading, no experimenting, there would be no arms and ammunition columns, for no one is interested in reading about standard factory products, the performance of which is well known.

Experimenting with arms and ammunition, and the absolutely free discussion of the same in the press, is an interesting phase of American life. It does not occur with any other class of products. The nearest approach to it is photography, but even that does not begin to compare with it. No editor of a photographic journal would dare to allow the complete damning of one product and unstinted praise of another which occurs time and time again in arms and ammunition columns in sporting magazines. And the manufacturers like it. As one of them said to the writer: "We don't care how much they criticise our products. What we are afraid of is that they will cease writing about arms and ammunition."

Let us now look into the details of hand loading and reloading and see how simple it is. The following is the brief procedure with rifle ammunition. Revolver and pistol ammunition differs from this only slightly.

Say the shooter has just fired some factory center fire cartridges, and wishes to reload the fired cases with either a load similar to the factory load, or a special load of his own. In factory ammunition the case is usually crimped on the bullet, and the fired case still retains a little of this turn-over at its mouth that would interfere with the smooth and straight seating of another bullet. So the first thing to be done is to run a little reamer into the mouth of the case and ream out the slight crimp. This also could be done with a sharp penknife if one was careful. Then, usually in the tool, a punch is inserted in the case and the fired primer is pushed out. This case has been expanded by firing so that it may be a little large for an easy and free loading in the chamber of the arm, and particularly its neck has been expanded so that the bullet would fit too loosely therein, and would fall out with handling. So the case is first wiped off outside with an oily rag so it will not stick in the die, and is then forced into the resizing die which resizes it to the correct dimensions, all except the neck which is usually resized too small for perfect bullet seating. Exact fit of the bullet in the neck, and its uniform tension therein is important for fine accuracy so that after resizing, a neck expander, ground to exact diameter, is run inside the neck to expand it to just the right size to hold the particular bullet friction tight. In general the diameter of the neck should be about .0015-inch smaller than the bearing of the jacketed bullet, or the

exact diameter of the bearing of a lead alloy bullet. The resizing and expanding should be exact, and should be done in a tool that operates in a straight line, this being assured by using the better grades of reloading tools. Usually the tool does these three operations—decapping, resizing, and expanding—all in one operation. It is only necessary to place the fired and slightly oil-wiped case in the tool and move the lever up and down once—as simple as that. Of course these operations are not necessary if one is using the ready primed, empty cases which can be bought from the cartridge manufacturer or its dealers.

The case now must be primed with a new primer. The primer is simply laid over the primer pocket and pressed down into it with the re-capping portion of the tool, care being taken to see that it is seated all the way down in the pocket. As each case is taken out of the tool a finger is drawn across its head so as to feel that the new primer is seated fully down in its pocket, this being one of the little forms of inspection or precaution that is taken after each operation.

The case is now ready to have the powder dropped in it. Tables in the manuals tell both the maximum charge that will be safe, and the minimum charge that will burn correctly, for all kinds of suitable powders, with all weights of bullets, together with the muzzle velocity that each weight of charge will give. From the table the reloader selects the particular charge he desires to use, and he adjusts his powder measure to throw this charge, fills the measure with powder, and then operating the lever of the measure, throws a charge of powder from the measure onto the pan of the powder scales to be sure it is the correct weight. It is necessary to thus verify the charge on the scales because none of the powder measures are infallible in their adjustments.

Now right here is a very important precaution. Beginning all over again by referring to the table of powder charges in the manual, and continuing to the setting of the powder measure and scales, he should check and recheck everything to be absolutely certain that the powder charge is correct. This is the one most important safety precaution, for it is so easy to make a mistake in reading the table, or in setting the graduations on the powder measure or scales, and thus make a mistake in the amount of powder used. The next most important safety precaution is to stop smoking *before* the powder can is opened.

A powder charge is then thrown directly from the powder measure into each case, simply holding the case mouth under the tube of the measure and operating the handle up and down. As soon as each case is filled it is stood upright in a row on the loading bench, or placed upright in a loading block that may be provided. As soon as all cases are filled with their powder charge another inspection is

made to see that all have the normal amount of powder, and that none is without its charge. This is easily done by simply looking into the mouth of each case in the row to see that powder stands to the correct height in all. Any great variation will be apparent at once.

It then only remains to seat the bullets. A bullet is placed or balanced central and base down over the mouth of the filled case, and the two together are slid into the bullet seater of the tool, a lever is pulled, and the tool seats the bullet to the correct depth in the case. This is all except to pack the loaded cartridges in a box labelled with the details of the particular load they contain. Instructions for operating each particular make of reloading tool, and telling how to adjust the resizing die, the bullet seater, and the powder measure come with the tool.

There are a few other little details, important in some cases and not in others, all of which are explained in the manuals. For example, after a case has been reloaded a number of times the primer fouling may cake in the corner of the pocket. This cushions the primer and also the primer does not seat firmly to the bottom of the pocket, leading to a low order of ignition or faulty ignition. The tool makers furnish a little rotary brush that takes this fouling out in a jiffy. 8-S bullets have very sharp base edges, and cases must not only have the crimp reamed out, but the case must be very slightly bevelled at the mouth so the bullet will easily enter without mashing down the case neck.

Never use a charge of powder greater than is advised in the tables of charges in the manuals. In fact a grain or two less than the maximum allowable is almost always advisable as giving better accuracy and longer life to the barrel. Rifle cartridges are reloaded for effective use in target shooting or hunting, and certainly a cartridge will be effective for neither if it blows out its primer or sticks so tightly in the chamber that it is extremely difficult to extract it—things that occur when the powder charge is a grain or so over the maximum advised. It is needless to say that a larger charge than this is extremely dangerous. Hence the precaution of checking and rechecking the powder charge as cautioned above.

In case there is any doubt as to the safety of a load one is assembling for the first time, load the rifle, weight it down with sand-bags, and pull the trigger with a string from cover. If the exact charge for a certain cartridge and bullet is not known, not mentioned in the tables, first start by loading with a very light charge, and then progressively with charges a grain heavier, trying each in the rifle. As soon as the primer appears to be flattened appreciably more than those in factory cartridges, or as soon as there is any indication of the case expanding unduly and being difficult to ex-

tract, stop increasing the charge at once, and lower that charge two grains for regular loading.

The mechanical powder measures are a great convenience for they greatly shorten the time necessary to fill each case with its load of powder. But they all give a very slight variation in the weight of the charges that they progressively throw. With the coarser grained powders the maximum variation may be as much as one grain, with the finer grained powders not more than .4-grain. The average is perhaps .3 grain, that is .15 grain over and under the standard charge. Nevertheless it seldom pays to weigh each charge of powder on the scales unless one is testing for velocity or pressure, or loading for 1,000 yard shooting or an important match. Ordinarily a difference of .7 grain in the powder charge of the .30-06 cartridge makes a vertical variation of only about six inches at 600 yards, that is one minute, and by the same token the .15-grain variation from the standard load would amount to only 1.29 inches at 600 yards, or .215 inch at 100 yards.

Some lots of bullets vary in individual weight, sometimes as much as a grain, but this makes still less variation in the vertical impact than a grain of powder, and it seldom pays to sort out bullets for uniformity of weight. It is probable that variations in bullet diameter cause a greater error, but the writer has not had the opportunity to determine how much. When small variations in weight or diameter do occur, powder charges being the same, the heavier or larger bullet will usually strike higher on the target, possibly because it develops a higher breech pressure, and also there may be a difference in the jump of the barrel.

But the above is no excuse for lack of uniformity or care. As a matter of fact when the greatest accuracy is required each powder charge should be hand weighed and bullets should be sorted for weight and diameter, for the algebraic sum of a variation of powder charge with a variation of bullet may cause a very appreciable variation at the target. Also cases should be selected by weight, for the outside of the case being sized to uniform dimensions, any variation in case weight means variation in the density of loading.

If a fired case requires greater or less effort to resize it than normal, if the primer or the bullet seats much harder or easier than normal, that assembled cartridge should be discarded where extreme accuracy or uniformity is desired. If these variations occur in the loading of more than one in twenty-five cartridges, stop and investigate to find the cause. Something is wrong somewhere, or one of the components may be faulty. As a matter of fact small variations in the tension with which the bullets are held in the necks of the cases will usually cause a greater variation, greater inaccuracy, than a grain or so variation in weight of powder or bullet.

In general the hand loading of revolver and pistol cartridges is similar in procedure and in precautions to the above, except that it is usually very desirable that the mouth of the case be firmly and uniformly crimped on the bullet. This is necessary to set up an initial pressure which will cause the quick burning powder to ignite and burn correctly and completely in the short barrel. It is also sometimes needed to prevent the bullets of cartridges in the cylinder or magazine from jumping forward in the necks of the cases from the jar of recoil and jamming the weapon.

In reloading rifle and pistol cartridges it is often possible for the careful workman to assemble ammunition which will be more accurate than the factory product. This is because he can select and use special components of proved fine accuracy which fit the individual weapon precisely, and because he can use a case which, by previous firing in the weapon he uses, has been expanded to fit its chamber precisely. As explained in Volume I, factory ammunition must be dimensioned and loaded so that it will fit freely and be safe and satisfactory in both maximum and minimum chambers and bores, in arms fouled or rusted, and in arms hot from repeated firing. The factory cartridge must also be entirely safe in arctic cold or tropical desert heat. This does not mean that factory ammunition as a rule is inaccurate. On the contrary it is usually remarkably accurate and uniform despite all these requirements.

There is one instance where factory ammunition has never been excelled in accuracy, really because it is specially selected ammunition designed for use in a particular lot of rifles. This is the National Match ammunition made at Frankford Arsenal, and the long range .30-06 target cartridges made by the leading cartridge manufacturers for use at Camp Perry. These cartridges are used practically exclusively in National Match rifles, and certain heavy, special long range target rifles (bull guns) both of which have chamber and bore dimensions very much closer to the established standard than other rifles of this caliber, and moreover these rifles, used only by fine competition shots, are invariably in most perfect condition. So the cartridge manufacturers can make this special ammunition with much smaller tolerances than regular trade ammunition. Cases are specially selected and ball-sized, powder charges are weighed, and bullets are of a special type and made in new dies. While the bullet machines are running, samples are taken from them and fired at once for accuracy, and thus there is an immediate check if machines happen to begin to turn out bullets not quite up to the high standard for accuracy. But other than in .30-06 caliber the careful hand loader can usually improve on factory accuracy, at least slightly, except in those particular and rare cases where a certain lot of factory ammunition happens to perfectly fit an individual rifle,

and largely when the bullet happens to be a particularly good one. Bullets apparently make more difference than anything else. Most hand loaders achieve fine accuracy by using a special bullet which has a reputation for fine shooting instead of the factory bullet. But many of these specially accurate bullets are made by processes so expensive in labor that no large factory could adopt them for quantity production without increasing the cost to a prohibitive extent.

As a rule it is not possible for a hand loader to assemble or reload shotgun shells which will approach the factory loaded shells either in pattern or uniformity. Generally speaking the hand loading of shotgun shells is indicated only when the greatest economy is necessary, or when factory shells are impossible to obtain, and components for reloading can be had. The reloads will be inferior to the factory product, but there is no reason why they should not be serviceable and safe, and perhaps equal to the shells we used to buy on the market twenty-five years ago. The reasons for this are fully set forth in Volume I, and in the chapter on Shotgun Ballistics herein.

The particular points that the writer started out to establish in this chapter were that handloading is simple and easy; that no great experience is necessary but only a careful following of the instructions in the best manuals; that if these instructions are followed it is entirely safe; and finally that it is very essential to the acquiring of any practical knowledge or interest in small arms ballistics. The writer has never heard of a lawsuit resulting from an accident in handloading. This does not mean that there have not been accidents, but rather that all occurring have been so evidently due to carelessness or ignorance in the part of the handloader that resort to the law to recover damages would not be successful. And just one other caution. Positively no one but an explosive chemist should attempt to make his own powder or primers, or to use these components when made by an amateur.

CHAPTER XIII

OLD RECORDS, EXPERIENCES AND OPINIONS

IT IS believed that certain old records and notes, preserved and compiled by the writer over a period of fifty years, may be of interest, and perhaps value, in showing the performance of old weapons and ammunition, the gradual improvement in materiel, old methods of testing and shooting, the formation of opinions, and particularly the experience that led to some of the thought, theories and facts set forth in the foregoing pages.

The experiments and tests, where not otherwise indicated, were performed by the writer. The reader should not suppose that these old tests indicate the performance that may be expected with modern weapons of the same caliber, and modern ammunition. But the tests do show the performance of much old materiel, and by comparison the great improvement that has taken place in the past fifty years or so. Most of the items are dated, and the date is important.

It was the general habit, prior to about 1920, to conduct accuracy tests of sporting rifles at 50 yards, and target rifles (other than .22 caliber) at 200 yards. It is regretted that more tests were not made at 100 yards (the present customary distance), however, a rifle and ammunition which made a certain size group at 50 yards would usually make a group just double that size at 100 yards.

Accuracy of Old Rifles. Fifty years ago the accuracy of our Government military rifles was given in official publications, and was more or less taken for granted. But we had very little direct evidence as to the accuracy of sporting rifles and their cartridges, and since then there has been much speculation as to it, and some erroneous opinions have been formed. Prior to 1900 almost the only evidence of accuracy we have consists in scores made in target practice, usually Schuetzen competitions, and this included only the scores of the winners, that is, selected arms in skilled hands, and did not give the average performance that could be expected. Moreover scores included too much of the human and luck elements.

Accuracy of Winchester Model 1886 Rifles. Particularly there was almost no evidence as to the accuracy of the black powder hunting

rifles, and yet it was in this class of arms that sportsmen were most interested. From 1890 until 1900 the Winchester Model 1886 lever action repeating rifle was generally considered the best American big game rifle for game larger than deer, and was becoming increas-

FIGURE 54

The official N.R.A. small bore target used in competitive firing at 100 yards has a 2-inch 10-ring in the center of an 8-inch black aiming bullseye. Inside the 10-ring there is also a 1-inch dotted X-ring which is used in deciding ties. That is, in a match, if two competitors get possibles, all shots in or on the 10-ring, the one having the greatest number of shots in the X-ring will win.

In home practice with the usual telescope sighted small bore match rifle, and in other firing, the writer has found it very convenient and economical, instead of using the official target, to draw a number of 2-inch heavy black rings on a sheet of white paper about the same size of the official target, or even on the reverse side of the official target. Six or more such circles can be drawn on such a sheet, and a 10-shot group can be fired on each. The cross-hairs or center dot of the telescope can be centered in this ring even more readily than in the 10-ring of the official target. Moreover, with a telescope sight of 12-power or more each bullet hole can be seen clearly as soon as the shot is fired, and there is no necessity of getting out of position between shots to look through a spotting scope. In fact the spotting scope is not necessary. All this is a great economy in time and targets.

The group here shown was fired by the writer at 100 yards, prone, in the course of his daily practice on his home range, and is one of the best groups under these conditions that he ever obtained—a 9X possible. Shot with a Remington Model 37 match rifle with 20 power Lyman Super Targetspot scope with Lee center dot reticule. Winchester EZXS .22 Long Rifle ammunition. Do not try to account for the shot off to the right—the writer cannot.

ingly popular in the West. Mr. A. C. Gould, the then editor of "Shooting and Fishing," a magazine devoted largely to rifles and rifle shooting (now known as "The American Rifleman"), probably had more range experience with this model of rifle than anyone else, and under date of December 26, 1899, he made the following remarks as to its accuracy with the various cartridges to which it had been adapted:

"Probably the .38-56 would prove the most accurate rifle. The .45-70-350 might be classed next in accuracy for it is very accurate up to 800 yards, and as for power, it has killed every game animal to be found in North America. The .40-82 and the .45-90 are less accurate than all the others. The .40-82 is capable of placing ten shots in an eight inch circle at 200 yards, but one of my correspondents states that with muzzle rest and Lyman sights the best he was able to do without cleaning was a 6½ inch group at 100 yards."

Test of .45-70 Winchester Single Shot Rifle, 1903-1904 30 inch, No. 3 half octagon barrel without rear sight slot. Lyman No. 2 rear

Range yards	*Elevation points*	*Group inches*	*Date*	*Remarks*
50	5⅛	2.12	9/02	W.R.A. black powder factory, 500 grain, benchrest, breathing through bore between shots.
50	5⅛	1.12	7/17/04	5 grs. du Pont No. 1 Smokeless, 65 grs. Hazards F.G. Black, UMC 7½ primer, 405 gr. Ideal bullet, 1 to 16, sized .456", Leopold's lubricant.
50	5	2.15	11/3/04	5 grs. du Pont No. 1 Smokeless. 65 grs, Hazards F.G. Black. Ideal bullet No. 456121, 1 to 16 sized .456", three bands exposed. Bench rest. "Holding very steady and pulling well. Most of deviation due to ammunition."
50	5	1.12	11/3/04	5 shots, bench rest, same load as immediately above.

Elevation with Lyman rear sight found on Essington Range in Philadelphia, 1902.

50 yards................	5⅛ points.
100 "	7¼ "
200 "	10½ "

The above seemed to be correct with both 405 and 500 grain U.M.C. black powder factory ammunition.

sight, and Lyman ivory bead windgauge front sight. Pistol grip stock of fancy walnut, checkered, shotgun butt-plate, sling swivels, and sling. Black powder ammunition fired exclusively. Bore was measured by William DeV. Foulke and found to measure .457-inch groove diameter, and to be very smoothly and evenly bored.

Tests of .40-72 Winchester Model 1895 Rifle. This was the same as the standard rifle of this model except it had a 30-inch, No. 3 Winchester half octagon barrel, Lyman receiver sight, Lyman ivory

Range	*No. of shots*	*Elevation*	*Date*	*Size group*	*Remarks*
50	7	2.75	8/2/05	.75″	Prone without sling. Rel.
15	3	2.75	"	.40	To obtain center of impact for groups shooting. .6″ above pt. of aim.
100	10	3.00	4/20/06	2.7	Prone without sling. Sun at 3 o'clock. Shots in 9 to 12 o'clock quarter of bull due to light.
50	10	2.75	7/24/06	2.6	Prone without sling. Fac. Group 2″ above aim.
50	10	2.50	3/21/07	2.3	Bench rest. Group 2″ high. Started fouled by 11 shots. Fac.
100	10	2.30	3/21/07	2.9	Bench Rest. Rel. Started bore clean oily. 1st shot is next to lowest.

Rel.—Hand load, Winchester cases, U.M.C. 7½ primer, 4 grs. du Pont No. 1 Smokeless, 68 grs. Hazards F.G. Black, Ideal 330 grain bullet sized .406″, 1 to 16, uncrimped. Leopold Banana Lubricant.

Fac.—Winchester black powder factory cartridge.

Shooting down hill. Horizontal distance 50 yards. Angle of depression 38 degrees. Elevation 2.75, or regular 50 yard elevation. Bullet struck 1″ above point of aim.

bead front sight, and a shotgun butt stock. Although it was a heavy piece, 10½ pounds, it was the writer's favorite big game rifle until the advent of reliable high power smokeless rifles, and he has never seen a better black powder hunting rifle. The .40-72 cartridge, using a 330 grain lubricated lead bullet, was Winchester's last development of a black powder cartridge, and was considered by them the best and latest development of such cartridges.

Many other groups were fired but the above are the most interesting, and are indicative of the rifle's regular accuracy. Much shoot-

ing was done with Winchester black powder factory ammunition during the spring of 1907 at Fort Crook, Nebraska. Rifle invariably shot excellently for the first ten rounds, but after that was often very wild due to accumulated fouling.

.32-40 Single Shot Rifles. The Schuetzen Rifle. Before World War I the .32-40 cartridge was considered our most accurate cartridge up to 200 yards, particularly when used in heavy single shot

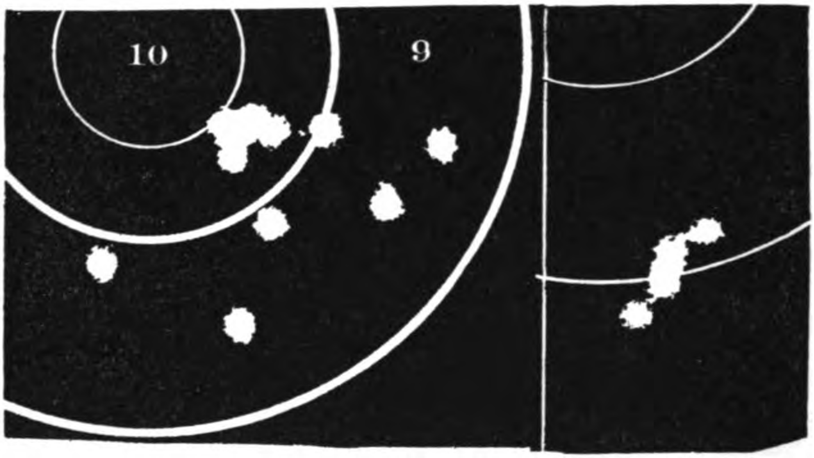


FIGURE 55

These two groups were fired by the writer in one of his .22 Hornet rifles at 100 yards, bench rest, with Winchester factory ammunition. They illustrate the erroneous impression that is always created by publishing the smallest or lucky group, and to some extent the difference between five and ten shot groups.

The left hand 10-shot group is a fairly average group for a good Hornet rifle with good factory ammunition. The 5-shot group is decidedly a lucky group, and smallest the writer has ever obtained with a Hornet rifle. The two groups measure 1.86 and .57 inches extreme spread.

Originally, a 10-shot group was considered the measure of accuracy for a rifle and its ammunition. Recently, 5-shot groups have become the fashion in testing hunting rifles because they save ammunition and time, and it is thought that in a hunting rifle the first five shots are the most important. But the 5-shot group is almost invariably much smaller than the 10-shot group, and this must be taken into consideration in comparing them. Had the right hand 5-shot string been continued for five more shots the group would probably have ended up about as large as the left hand one.

rifles, and in Schuetzen rifles used for 200 yard offhand target shooting. Not including the Pope muzzle-breech loading rifles which were our most accurate rifles, bar none, until the recent improvement of ultra small bore, high intensity cartridges, the .32-40 made its repu-

tation entirely based on its use in heavy single shot rifles, where the bullet, either paper patched or grooved lubricated, was pre-seated in the bore ahead of the case. With fixed ammunition, bullet seated to full depth in the case, and black powder, it was most decidedly not a finely accurate cartridge, except that about 1910 the Winchester Repeating Arms Company produced a low power smokeless cartridge loaded with soft point metal cased bullet of 165 grains that was superbly accurate. The reasons for the accuracy of this particular cartridge have never been fully understood by the writer.

The extent to which the old time riflemen used to go, and the extensive experiments they conducted, in order to obtain fine accuracy in their old .32-40 rifles is well illustrated in the following letter from Frank Evans, an old time Schuetzen rifleman, to the writer under date of April 15, 1913:

"There is a wide difference of opinion as to what temper bullets should be to shoot the best, and nearly every rifleman of any experience is willing to break a lance in defense of his favorite alloy. I have one shooting friend in the local club who has a first class .33 Pope muzzle loader. He moulds his bullets very carefully from a mixture of tin and lead, 1 to 15, and he has rather a hard time seating them according to my notion. But he can certainly shoot a fine rest group any time he wants to. If he changes to a softer bullet the accuracy is lost, and if he shoots a grain more or less of powder, it immediately shows a wider group.

"I have a Pope .33 cal. muzzle loader that takes a bullet identical with his. I try to use a bullet 1 to 25, but that is approximate only as I use old printer's type to harden my bullets instead of the more expensive tin. My barrel is not quite as good as his as it is a No. 3 while his is a No. 5 barrel. Mine has more vibration, but my groups will average about as good as his, and in a 50-shot rest match it is nip and tuck between us. I have given him ten bullets of mine several times to try, and when he used my load they did just as well as his own bullets. He shoots a No. 2½ U.M.C. primer, 7 grains of Lesmok priming, and 36 grains of Schuetzen smokeless, all measured in an Ideal measure. I shoot exactly the same load except I use 34 grains of Schuetzen instead of 36.

"I have been thinking on this particular line for the past ten years, and I have come to the following conclusions:

"The temper of the bullet depends to a great extent on the fit of the bullet. To illustrate: Suppose—this is all illustrative theory both as to pounds pressure and diameters—it takes 500 pounds pressure to upset a bullet .319-inch in diameter and tempered 1 to 40 to fill a groove diameter of .321-inch. A powder charge that just meets that requirement would shoot A-1. Now suppose the bullet was .320″ in diameter and tempered 1 to 20. A powder charge that would just

upset it to fill a groove diameter of .321″ would be right and should shoot equally well.

"I believe this theory is correct in this way, that the powder charge must be just sufficient to upset the bullet to fill the grooves to make good shooting. If it exceeds that point it deforms the bullet. This is the reason to my mind that an express rifle lacks accuracy. Accuracy is not regained, in the case of increased velocity, until we use a jacketed bullet, which of course is not deformed by the excessive blow—that is, excessive as compared with a lead bullet.

"I have not used a Winchester barrel for several years as the wide lands are a little against easy and accurate bullet seating. However, I used them for many years and I must say that of eight to ten .32-40 barrels I have purchased from Winchester I never had a poor shooting one, and some of them were gilt edged. If you get a barrel from them that is smoothly and evenly cut I believe you will get satisfactory results with the following combination:

"U.M.C. Primer No. 2½. 6 grains Ideal Measure King's Semi-Smokeless F.G., or 7 grains of Lesmok F.G.; 33 or perhaps 34 grains of Schuetzen powder; no wad if you can reload without its being necessary, or a post-card wad. Ideal Bullet No. 319273 or 319162, tempered 1 to 20 or 1 to 25, and sized .0005 to .001″ smaller than groove diameter of rifle. This primer and powder combination you can use for the rest of your life and never injure your barrel in the slightest, with almost any old method of cleaning.

"I am going to send you a bullet seater like I use. It is very easy to manipulate in a Winchester action. Make a 'starter' out of an 8-inch length of broom-stick. Flatten one end on opposite sides so it will slip into the action over the breech block when the action is opened. Fix a knob to the other end of the starter. Hold the rifle in the hollow of the left arm, insert the seater with bullet, place starter against seater plunger and hold in place with left hand, hit it a blow with palm of the right hand a la muzzle loader. The blow will generally send it forward far enough for the breech block to engage it when closing the breech. Closing the breech will put the bullet to the exact place each time. If the Winchester people make their chambers like they did when I bought my last barrel from them, the plunger of the bullet seater should be a little less than 1/16-inch longer than the shell. I will make the one I am sending you that length.

"I have never been seriously interested in high power rifles. Getting too old I guess, and it is somewhat difficult to find room to use them. All troubles of myself and shooting friends have disappeared since we have all adopted the above load, or rather the No. 2½ primer, which of course calls for a priming charge of black powder or its equivalent." Frank Evans.

Practically all Winchester .32-40 barrels had a groove diameter of .320 to .321-inch. The bullets in factory ammunition measured .319-inch, and were seated deeply in the cases. Very much better accuracy could be obtained by sizing bullets to .321-inch, and seating them projecting slightly more from the mouth of the case so that their ogive contacted the lands in the leade. The writer has a .32-40 rifle, 30-inch No. 3 Winchester half octagon barrel and Ballard breech action which he shot considerably in times past with a load consisting of Ideal Bullet No. 321232, 170 grains, cast 1 to 32, and sized to .321-inch, seated with two bands exposed outside the case. The powder charge was 36 grains of Hazards F.G. black powder with a priming charge of 4 grains of du Pont No. 1 Smokeless, with the U.M.C. No. 7½ primer. The following tabulation gives four groups fired from bench rest with this rifle and load in the year 1905, 10 shots in each group:

Range, yards	*Size of group*	*Sight*	*Elevation*	*W.G.*	*Remarks*
50	1.375″	Lyman	1½ pts.	0	
50	.94	"	1¾ "	0	
100	1.00	"	2⅓ "	0	Probably lucky group
50	1.08	Scope	5-7 "	8-5	Loaded 1906, fired 6/16/11

At one time du Pont Schuetzen Smokeless powder was tried with the above bullet, and the charge that du Pont recommended to equal the factory black powder load. The action was blown partly open and the hammer to full cock. The Ballard breech action was not a particularly strong one, although excellent for .22 rim fire and light black powder cartridges. The Ballard was at one time adapted to such cartridges as the .45-70, and the .40-90-370, but it is understood that when fired extensively with these heavy charges the action soon developed looseness, although the writer never had any experience with it using such heavy black powder loads.

The .25-20 Single Shot Cartridge. Mr. J. F. Rabbeth deserves credit for originating the .25 caliber rifle in America. He wrote the first article advocating such a caliber in "Shooting and Fishing" of April 18, 1889, and for three years prior to this he had been experimenting with a rifle of this caliber made to order for him by the Remington Arms Company. The case was made by necking down the case of the .32 Wesson rifle. The charge was 32 grains of Hazards Ducking Powder and a 76 grain bullet. The 200 yard trajectory was but 7 inches. Experiments with this rifle led to the

placing on the market of the .25-20 Single Shot cartridge in the summer of 1889. The Maynard was the first rifle adapted to it, followed several weeks later by the Stevens rifle. The cartridge was first made by the Union Metallic Cartridge Company. The cartridge became very popular at once, and was easily the most popular and used small game cartridge around the turn of the century.

On May 30, 1894, Major George Shorkley, a very skilled rifleman of his day, made twenty-one consecutive 8-inch bullseyes with a rifle of this caliber equipped with a telescope sight. The charge was 18 grains of black powder and a 77 grain bullet. This at 200 yards.

The .25-20 was the favorite small game cartridge of the writer for many years, and he did a great amount of experimenting and hunting with it in a number of rifles, mostly Winchester single shots. For many years he used F.G. black and Kings Semi-smokeless powders with 77 and 86 grain Ideal bullets, and later with an 80 grain bullet cast in a Pope mould and lubricated with a Pope lubricating press, which was slightly better. Groups ran around 1½ inches at 50 and 3 inches at 100 yards, which was excellent for those days. Then he started in with smokeless powder and 86 and 87 grain jacketed bullets, and finally evolved a charge consisting of the 87 grain Savage pointed, metal cased, soft point bullet, and 8.5 grains of Schuetzen Smokeless powder. The primer was the Winchester No. 1-W, a smokeless chlorate primer. Muzzle velocity was about 1600 f.s. This load steadily gave .68 to .80-inch ten shot groups at 50 yards, and 1.5 to 2.0 inches at 100 yards. But despite the fact that the bore was invariably cleaned with stronger ammonia not later than the evening of the day on which the rifle was fired, in about 500 rounds the barrel was completely ruined by pitting. The reason for this was not then known, but of course it afterwards developed that it was caused by the chlorate primer. With such a small powder charge the chlorate fouling of the primer was not diluted to any great extent, and the seeds for pitting were laid almost immediately. With modern non-corrosive priming this is of course now a thing of the past.

The .25-20 W.C.F. Cartridge. At this same time the writer also had a Winchester Model 1892 repeating rifle for the .25-20 W.C.F. cartridge, and he had been getting most excellent accuracy from it with the Winchester low pressure smokeless cartridge. The rifle was fitted only with Lyman hunting sights, but despite the inherent slight errors of aim with such sight equipment the rifle averaged 1.57-inches for ten shot 50 yard groups, which was really excellent in those days. The cartridges were loaded with 86 grain soft point bullet and Sharpshooter powder. But despite the most careful cleaning the barrel was ruined by pitting in about five hundred rounds. The writer wrote to the Winchester Repeating Arms Company

relative to this accuracy and also the pitting of the bore, and under date of May 24, 1912 received the following reply from them:

"In regard to the ammunition you have been using, we load these cartridges as well as other sizes with Sharpshooter powder because the accuracy obtained is excellent. But when you ask us to criticise this powder (I did not—T.W.) you put us in a very embarrassing position, for we naturally occupy a neutral position on the powder question, using powders manufactured by the different powder concerns. We feel, therefore, that it would be better and more satisfactory to all concerned if you would take up with the powder company the question of the effect of Sharpshooter powder on rifle barrels. We note the manner in which you clean your gun, and do not see how it could be improved upon."

As a matter of fact it was not the powder that was causing the pitting and rusting at all, but the potassium chloride in the chlorate primer fouling, diluted scarcely at all by the fouling of the small powder charge, as explained above. But that was not known at that time. About 1939 the Remington Arms Company showed the writer a .25-20 Winchester Model 1892 rifle with plain steel barrel that had been used as a testing piece in their laboratory, and had been fired many thousand rounds with smokeless powder, jacketed bullets, and Kleanbore primers, and without any cleaning. The bore was as good as when new. No one knows the accuracy life of a .25-20 barrel with modern non-corrosive ammunition—it is exceedingly long, possibly in excess of 30,000 rounds.

But despite the above the writer was exceedingly fond of the .25-20 cartridge, and this induced him, in 1927, before the introduction of non-corrosive primers, to obtain another Winchester single shot rifle in .25-20 W.C.F. caliber, and with a stainless steel barrel that Winchester was producing at that time. The .25-20 W.C.F. cartridge was chosen instead of the .25-20 S.S. because rifles were no longer being manufactured for the single shot cartridge and it was felt that it was only a question of time when .25-20 Single Shot cartridges and empty cases would be difficult to obtain. This rifle has been fired very little because of the advent of the .22 Hornet and other high intensity .22 caliber cartridges which absorbed much of the interest in small game rifles. But two charges have been developed for it, both with the Winchester No. 116 non-corrosive primer. One charge, believed to be most excellent for wild turkeys, consisted of the 86 grain metal cased soft point bullet and 9 grains of du Pont No. 4227 powder, M.V. about 1500 f.s. in 26 inch barrel, and shooting steadily into 1.5 inches at 100 yards. The other charge, believed to be ample in killing power for coyotes, consisted of the same bullet and 11.5 grains of the same powder, M.V. about 1825 f.s. In both loads the bullets were seated far enough out

of the case to contact the bullet seat. Such loads would not be practical in a repeating rifle where the loads developed by the du Pont Company should be followed. The latter coyote load averaged 1.8-inch groups at 100 yards.

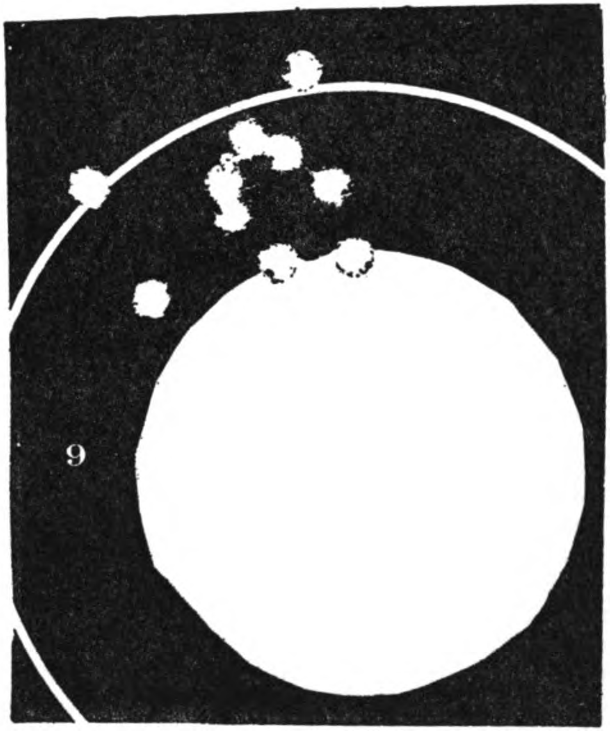


Figure 56

This group was fired at 100 yards, bench rest, with the writer's Winchester Model 70 rifle, barrel relined by J. E. Gebby for the .22-3000 Lovell R-2 cartridge. The load was 15.8 grains of du Pont No. 4198 powder, the 55 grain Sisk-Niedner soft point bullet, and Winchester No. 116 primer. The 10-shot group measures 1.4 inches. This was the most accurate bullet for this rifle before the advent of the Wotkyns-Morse 8-S bullets.

Aim was taken at the center of the white bullseye, and the scope was accurately adjusted to strike one inch above the point of aim at 100 yards. But this group centered 1½ inches high and ½-inch to the left. Such small differences in the location of the center of impact frequently occur, probably due to a number of causes, the chief of which are not assuming exactly the same firing position each time with consequent change in jump, and to weather conditions. Therefore it is best to fire a number of groups and average them to determine the average center of impact, drop of bullet, or trajectory height. This has been done with this rifle, and it does *average* centering its groups just about one inch high at 100 yards with this sight adjustment of E12.5W132.

Jump of .25-20 Single Shot Rifle. On October 14, 1914 some rough but interesting tests were made to determine the jump and effect of resting the rifle. The rifle was one belonging to the writer, Winchester single shot with 28-inch No. 3 round barrel, standard Winchester forearm. Range 50 yards, and load 8.5 grains Schuetzen and 87 grain .250-3,000 Savage soft point, pointed bullet. All shooting with the same sight adjustment and point of aim. Shooting from bench rest, in group No. 1 measuring 1.16-inch the forearm was rested on rubber pad, and in group No. 2 measuring 1.29-inch the naked barrel rested on a pine board 6 inches from the muzzle. The center of impact of group No. 2 is 1.42-inch above group No. 1.

At 50 yards, with the above adjustment of the scope, correct for standard bench rest shooting, to give center of impact in center of bull, scope alined on the center of the bull, a sight on the target through the bore struck the target approximately 4 inches above the center of the bull, thus showing very distinctly a downward jump of this barrel on firing.

Early Accuracy of .22 Long Rifle Cartridges. In view of the remarkably fine accuracy of the match grades of present manufacture of the .22 Long Rifle cartridges, it may be interesting to note the accuracy obtained from the regular manufacture of this ammunition thirty years ago. In 1911 the writer procured a Winchester Single Shot rifle for the .22 Long Rifle cartridge. The rifle had a 26 inch No. 3 round barrel, and double set triggers, and was supposed to be the most accurate .22 rim fire rifle of those days. Between 1912 and 1915, when he went to Panama, he did a great amount of target

Tests, Spring of 1912, Fort Jay, N.Y.

Ammunition	*25 Yards*			*50 Yards*			*100 Yards*		
	Elev. ½ min.	*W.G. ½ min.*	*Group In.*	*Elev. ½ min.*	*W.G. ½ min.*	*Group In.*	*Elev. ½ min.*	*W.G. ½ min.*	*Group In.*
Rem-UMC Lesmok	71	61½	.75	72	61½	1.95	84	62	3.96
Winchester Lesmok	71	62	.90	76	62	2.00	92½	61	4.03
Peters Semi-Smok	69	60	.60	72	59	1.30	86½	58	2.61

Of the three lots of cartridges tested at this time this rifle evidently preferred the last.

shooting with this rifle, including a number of accuracy tests firing the rifle from bench rest. It was fitted with a Winchester A-5 telescope sight, No. 2 rear mount reading to half minutes. In each case the sight adjustment has been corrected so as to bring the center of the group into the center of the bullseye—standard N.R.A. targets. The difference in sight adjustment therefore shows the difference in jump with the various makes of ammunition, despite the very heavy barrel. There could have been practically no difference in trajectory for the muzzle velocity of all the cartridges was practically the same, about 1050 f.s. Incidentally the variations in sight adjustment required also shows the need for finely adjustable sights.

Test of May 31, 1914

Ammunition	*Condition of bore*	*25 yards*			*50 yards*		
		Elev. ½ min.	*W.G. ½ min.*	*Group In.*	*Elev. ½ min.*	*W.G. ½ min.*	*Group In.*
U.S. Lesmok 1914	Clean Cold	75	55	1.00			
"	Fouled 10	75	56	.65			
"	Fouled 20	75	57	1.01			
"	Fouled 30				79	57	1.33
"	Clean Cold	73	56	.60			
"	Fouled 10				74	56	1.62
U.S. Lesmok 1912	Fouled 40	71	56	1.05			
Peters crimped SS 1914	Clean Cold	71	55	.62			
	Fouled 10	71	56	.70			
	Fouled 20				76	56	1.67
W.R.A. Lesmok 1913	Clean cold	75	55	.50			
	Fouled 10	74	56	.75			
	Fouled 20				79	56	.78
Rem-UMC Lesmok 1912	Fouled 30	73	56	.50			
	Fouled 40	73	56	.70			
	Fouled 50				75	56	1.70

There had been some discussion as to the accuracy of Winchester .22 Long Rifle cartridges in 1912, and accordingly in December 1912 Mr. A. L. Laudensack of the Winchester Company and the writer made the following accuracy tests at 25 yards in the gallery, bench rest. Laudensack used a Winchester single shot musket, and

the writer used his Winchester single shot as above. Both used the Winchester A-5 Telescope sight.

Ammunition	Size of group shot by	
	Laudensack	*Whelen*
Winchester, Lesmok, New	.50″	.45
"	.72	.50
"	.91	.46
"	.65	
"	.54	
" Average	.662	.47
Rem-UMC Lesmok Open Market	1.02	.94
U.S. Lesmok Open Market	1.40	.50
Peters Semi-Smokeless O.M.	.92	.70
"	.90	.47
"	.71 *	
" Average	.842	.585

* Shot by Whelen with Laudensack's rifle.

In 1918 the National Rifle Association instituted competitive Small Bore Rifle Shooting outdoors at 50, 100, and 200 yards. In their efforts to develop a rifle for this sport the Winchester Company first used the Winchester Single Shot action, but they found that they could not obtain the necessary fine accuracy with it in .22 Long Rifle caliber, probably due to lack of perfect ignition and the two-piece stock. For perfect ignition the .22 Long Rifle cartridge requires that a very tight headspace be maintained. Accordingly they decided to develop an entirely new arm for this sport, and the result was the famous Winchester Model 52 rifle. This Model 52 rifle with recent lots of match ammunition has frequently shot steadily into an inch or less at 100 yards.

There is considerable difference in the accuracy obtained with different lots and makes of regular trade .22 Long Rifle cartridges, more so in fact than the difference in accuracy between different makes and models of well made rifles. Consequently most of the competitors in small bore matches use special match ammunition, made with many refinements, for which an extra charge is made. The beginner often asks how accurate a certain make and model of .22 rifle is. This can never be told without a thorough test of that

individual rifle with a number of lots of ammunition. But it is almost certain that it will shoot very much more accurately with match ammunition than with that bought through the customary trade.

Accuracy of Lever-Action Rifles. Between 1902 and 1925 the writer undertook literally hundreds of accuracy tests with various lever action rifles, both the older ones for black powder cartridges, and the more recent models for high power smokeless ammunition. It would not be profitable to burden these pages with the details of even a small portion of these tests, but a summary of the results may be of interest.

It should be understood that practically all of these American lever action rifles, including also the pump actions for center fire cartridges, are intended for deer and other big game shooting at moderate ranges, usually in forested country. The target is large and the distance short—practically never over 200 yards, averaging possibly about 75 yards. If the first shot should fail to stop the beast, it is very desirable that it be possible to deliver a second or third shot rapidly before the animal is hidden by the brush. Lever action rifles are pre-eminently suitable for such use. Their accuracy is ample, and the trajectory to 200 yards, which is about the limit of their sure hitting range, is sufficiently flat even with the older smokeless cartridges with muzzle velocities around 2000 f.s. They are decidedly not long range rifles or target rifles.

Most of these accuracy tests were conducted at 50 and 100 yards, shooting from bench rest, center of forearm resting on a soft pad. Almost all rifles were fitted with Lyman aperture rear sights having a cup disc screwed in the large peep, and a gold bead front sight that was smoked black. An error of aim, as compared with aim through a scope, and amounting to about one-half to one inch at 100 yards, was therefore present in most of the tests, and this must be taken into consideration. In the following summary the accuracy is given in terms of extreme spread at 100 yards; that is where a test was conducted only at 50 yards, the group diameter has been doubled to give approximately what it would have been had the rifle been fired at 100 yards.

Black powder rifles using factory ammunition loaded with black powder and lead bullets, quite regularly gave groups about twice the diameter averaged by high power smokeless rifles. This is in keeping with the findings of sportsmen about 1899 to 1905—that is, that these new high power rifles were much more accurate than the old black powder arms to which they had been accustomed. But this is not quite a correct statement because when these black powder arms were tested with freshly hand loaded cartridges, black powder not unduly compressed, cases not crimped on the bullet,

bullets freshly lubricated and sized to exact groove diameter in an Ideal lubricating and sizing press, the accuracy was just as good as

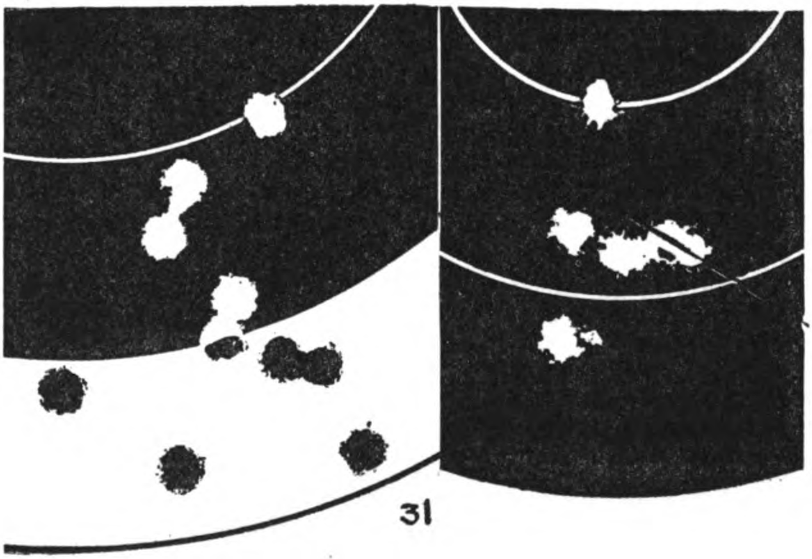


Figure 57

These two groups were fired from bench rest in an accuracy and trajectory test. The rifle was a standard Winchester Model 70 for the .257 Roberts cartridge, fitted with a Lyman Alaskan 2½ power scope with flat top post reticule. The load was the 100 grain Western Tool & Copper Works bullet, 40 grains of du Pont No. 4320 powder, and Winchester No. 120 primer, M.V. 2900 f.s. Aim was taken at the bottom of the bullseyes.

The group on the left was fired first at 200 yards, the sight being adjusted to strike the point of aim. This group measures 1.88 inches extreme spread. The right group, six shots only, was immediately fired at 100 yards, taking care not to change the position or tension of holding at all from that used for the 200 yard group. It measures 1.26 inches.

The center of the 100 yard group is 1.5 inches above the point of aim, therefore, with sights set for 200 yards, this load will center 1½ inches above the point of aim at 100 yards—the practical hunting trajectory.

To obtain the true trajectory, above the line connecting the center of bore with center of bullet hole in the target, add to the above trajectory one-half the distance from the axis of bore to the line of sight, in this case .60 inches, which makes the true trajectory height over 200 yards 2.10 inches. The Winchester table gives the trajectory height for 100 grain bullet at 2900 f.s. as 2.5 inches, but their bullet is a rather blunt pointed one, while this W. T. & C. bullet has a rather sharp point.

for high pressure smokeless loads in the newer rifles. That is for the first five shots, after which the accumulated black powder fouling was often detrimental to the accuracy.

There is one detail that the writer regrets very much about these old accuracy tests of his. The groups recorded almost all contained ten consecutive shots, it being customary in those days to fire 10-shot groups. Subsequent tests have proved that with lever action rifles the first five shots fired from a lever action rifle, starting with the rifle cold, will make a much smaller group than when ten shots are fired. The accuracy appears to fall off at least a little, often considerably, when the barrel becomes very hot during the last five shots of a ten-shot group. This is possibly due to the slight bending of the barrel as it becomes overheated from repeated firing, and the restriction of its expansion by the fittings of the tubular magazine and forearm. Of course it is the accuracy of the first five shots only, starting with the barrel cold, that is of importance to the hunter, and as a rule this accuracy is slightly better than the writer's ten shot tests would indicate.

Lever action rifles adapted to light cartridges are almost always more accurate than those taking heavier loads, or loads of higher breech pressure, for the reasons given in Volume I. Particularly, as explained several times, other things being equal, the heavier the barrel of a rifle the more accurately will it shoot. The barrel of a .25-20 repeating rifle, for example, is much heavier in proportion to its cartridge than is, let us say, the barrel of the usual lever action rifle taking the .30-30 or the .348 Winchester cartridges.

Among the most accurate of these rifles that the writer has tested are those taking the .218 Bee, .25-20, .250-3000, and .32-40 cartridges. The .25-20 Winchester Model 1892 rifle when tested with low power smokeless cartridges, 86 grain metal cased, soft point bullets, grouped steadily in 2½ to 3 inches at 100 yards. Winchester states that this cartridge will group in 2 to 2½ inches, but their tests have been quite regularly conducted with rifles fitted with a telescope sight. Their .218 Bee rifle fitted with a telescope sight grouped in 2 to 2½ inches.

The .32-40 Winchester Model 1894 rifle when tested with black powder factory cartridges gave quite mediocre accuracy; but in later years when shot with Winchester low pressure smokeless cartridges loaded with 165 grain metal cased soft point bullet the accuracy was very fine, groups often being as small as 2 to 2½ inches. Groups measuring 2½ to 3 inches were often obtained from .25-35 and .25 Remington cartridges.

The most accurate lever action deer rifles tested were four .250-3000 Savage Model 1899 weapons having regular weight (not featherweight) barrels and solid frames. Two of these rifles which were fitted with scopes grouped quite consistently in 1¾ to 2¼ inches with certain lots of ammunition. These rifles were quite stiff from muzzle to butt and thus their jump was uniform. This desirable

stiffness was assured by the butt-stock being secured to the receiver by a heavy through-bolt instead of by tangs. Also the barrel fitting is similar to that of the older single shot rifles, there being no tubular magazine under it. The advantage of this construction also showed up in the case of the older .303 Savage Model 1899 rifles which in all instances gave slightly better accuracy than did the .30-30 and .32 Special rifles having tang stock fittings and tubular magazines.

Many tubular magazine rifles in .30-30 and .32 Special calibers were tested. They shot into 3½ to 4½ inches with Winchester and U.M.C. ammunition loaded with 160 to 170 grain soft point bullets. Winchester has stated that they will group in 3 to 3½ inches, but here again their tests were probably conducted with scope sighted rifles. The writer was privileged to see a number of .30-30 ammunition acceptance test targets fired at 100 yards, which ran from 2½ to 3 inches, but these were made with a scope sighted Winchester Model 54 bolt action rifle.

(The Winchester Model 70 bolt action rifles for the .250-3000 cartridge are fully as accurate as any of the other calibers of cartridges to which this model is regularly adapted, except only the .220 Swift which is slightly more accurate than any of the others. This of course to about 300 yards or a slightly longer range. Beyond 600 yards nothing has surpassed the .30-06 and .300 H. & H. Magnum target varieties of cartridges in well made bolt action rifles.)

In 1940 the writer made several accuracy tests of a .348 caliber Winchester Model 71 rifle, one of the most heavily charged lever action rifles. With 200 grain ammunition at 100 yards, with peep sight, it grouped in 3 to 3½ inches for five-shot groups starting with the barrel cold, excellent for so heavy a rifle, or rather so heavy a cartridge in a lever action rifle. But this cartridge had the advantage of being loaded with a modern powder, a much more uniform and suitable propellant than the powders commonly used in rifle cartridges from 1902 to 1925, the period when the majority of these tests were made.

Rather mediocre accuracy was always obtained from the now discontinued Winchester Model 1895 rifles for the .30-40, .30-06, and .35 W.C.F. cartridges. This model was not handicapped with a tubular magazine under the barrel, and the writer can assign no cause for its ordinary performance except the heavily charged cartridges in an arm with the breech block locked and supported at its rear end, and the two-piece stock with butt-stock secured to the receiver by tangs. Groups ran quite regularly 4½ to 7 inches at 100 yards.

The writer believes that if a sportsman is testing a tubular magazine lever or pump action rifle for accuracy, and is adjusting its

sights for hunting, he should base all his work on firing groups of three to five shots, starting always with the barrel cold, and that the magazine, particularly if a full length one, should not be loaded with more than three cartridges at any time. These rifles are likely to shoot to an entirely different center of impact when the barrel becomes hot from repeated firing as after five consecutive shots, than they do when the barrel is fairly cool, and the accuracy in the hot barrel will be disappointing. Also sight adjustment based on the grouping of a hot rifle will seldom be correct for the same rifle when cold or slightly warm. Almost invariably shots fired at game will be delivered from a cold rifle. Once again, so as not to be misunderstood or misquoted, these remarks apply only to tubular magazine lever or pump action rifles for big game cartridges, not to bolt action rifles, Savage Model 1899 rifles, nor .22 rim fire rifles.

There has been considerable improvement in both rifles and ammunition since the writer made his tests, even though breech actions and cartridges and their bullet weights remain the same. Modern lever action barrels do not vary so much from standard groove diameter as did those of twenty to thirty years ago. Cartridges are loaded with better propellant powders, and the primers are likewise better. Most of these newer deer and big game rifles and their new ammunition now group in possibly 2¾ to 3½ inches at 100 yards. This means eight inches or slightly less at 200 yards. For years and years sportsmen with very wide experience the world over have stated time and time again that a rifle and its ammunition was not suitable or altogether sportsmanlike for big game shooting at distances greater than that at which the hunter, shooting coolly on a rifle range, could not group his shots steadily in an eight inch bullseye. By this measure our lever action rifles are perfectly satisfactory for big game up to two hundred yards.

The following extracts from the writer's correspondence may be interesting in connection with the accuracy of the above class of rifles. The dates are important. Thirty years ago there were no American riflemen better qualified to test a rifle for accuracy than A. O. Niedner and the late Captain Edward C. Crossman:

"In regard to the .35 caliber Winchester Model 1895 rifle for accuracy; last fall one of my customers had a brand new one of these rifles on which I did some work and shot at 100 yards. The best group I could make from bench rest was an eight inch group. This is a powerful cartridge, and no doubt plenty accurate enough for game like deer or moose shot at the regulation distance of 50 to 75 yards. It is not a caliber which you or I would pick for a target rifle."—A. O. Niedner, Feb. 25, 1914.

"Shooting a friend's .33 Winchester (model 1886) the other day from rest we got a 14-inch group at 200 yards, and although he de-

nies that this is the best the rifle will do with soft nose stuff, yet he has not proved his point so far." E. C. Crossman. Dec. 29, 1913.

It has been stated in Volume I that as a rule lever and pump action rifles are chambered more loosely than bolt action rifles, because they lack the extracting power of the latter type of arms, and the chamber must be looser to enable them to extract the fired cases, particularly when the barrel is hot from repeated firing. Such loose chambers are thus desirable in lever action rifles to prevent failures to extract and jamming of the rifle. Either loose chambers, or excessively tight chambers make for mediocre accuracy. The following note from the writer's records is interesting in this connection:

Measurement of chamber: Some measurements of cases and bullets were made April 6, 1919. New .33 W.C.F. cartridges measure outside at the neck .3605 to .3607 inch. Cases fired in .33 Model 1886 rifle measure .3660 to .3663-inch. Bullets measure .3360 to .3363-inch. These for U.M.C. cartridges, cases and bullets. Difference between neck measurements of new cartridges and fired cases—Max. .0058-inch, Min. .0055-inch. For comparison U.S. Rifle M 1903 (Springfield) No. 495883 shows a difference between necks of loaded cartridges and fired cases of Max. .0034-inch, Min. .0022-inch, showing a much larger chamber for its cartridge in this .33 caliber rifle.

Experiments with Worn Muzzle. Thirty years ago it was the opinion of everyone that if the muzzle of a rifle barrel became worn, as from the friction of the cleaning rod, the barrel became inaccurate and useless unless the barrel was cut off to shorter length, and the muzzle properly crowned.

In May 1913 the writer conducted the following experiment with his .30-40 Winchester Single Shot rifle which had a 30-inch No. 3 barrel, a quite accurate piece. The shooting was at 100 yards, bench rest. The rifle was sighted with a Winchester A-5 telescope sight, No. 2 rear mount reading to half minutes. Groups 1, 2, and 3 (see following table) were fired with the muzzle perfect, that is as it came from the factory. The muzzle was then slightly deformed (worn) on its lower half to approximately what would occur from years of careless cleaning from the muzzle. The lands were worn down (with a rat-tailed file) to the bottom of the grooves, and on under side only the wear was continued until the grooves themselves were worn down about .003-inch. The bevelling was thus oval in shape, greater at the bottom of the muzzle than at the top. Groups 4, 5, and 6, were then fired with conditions identical with groups 1, 2, and 3, but with the muzzle worn in the above manner.

In the table the sight readings have been corrected to bring the center of impact of each group to the point of aim. It will thus be seen that after the muzzle was deformed the rifle grouped its shots

on an average 1.33-inch to the left of where it grouped them before. With one lot of ammunition it grouped 1.25 inch higher after deforming than before, but with the other two lots of ammunition there was no difference in the elevation. The most remarkable part of the test, however, was that the rifle shot each lot of ammunition more accurately with the deformed muzzle than with the perfect muzzle. This is believed to be merely an incident. Particular attention is called to the last group fired (No. 7) which was with very old ammunition which had been in the writer's possession over seven years. It shows what may be expected from a rifle that has been used for years and well cared for, except that it has been cleaned from the muzzle, and shot with the kind of ammunition one

EXPERIMENTS WITH WORN MUZZLE
.30-40 Winchester Single Shot Rifle, May 1913
100 yards, Bench Rest

No.	*Ammunition All 220 grain bullets*	*Mean radius In.*	*Group measure In.*	*Elevation ½ minutes*	*Windage ½ minutes*
1	Rem-UMC soft pt.	.982	4.20	72.5	91
2	Win. soft point	1.183	3.30	80.4	91
3	Peters, soft pt.	.852	3.80	83	93
4	Peters, soft pt.	.630	2.82	83	95.5
5	Win. soft point	.620	1.75	80.5	94.5
6	Rem-UMC, soft pt.	.691	1.70	75	94
7	Win. S.P. 1906	.486	1.33	84	95.5

The above were all ten-shot groups.

might find in frontier stores. In groups 1, 2 and 3, if we take the Rem-U.M.C. ammunition as a standard we see that the Winchester ammunition grouped 4 inches lower, and the Peters ammunition 5.25 inches lower and 1 inch left. This was not due to velocity because all cartridges gave the same muzzle velocity—1960 f.s. Rather it was due to the different jump of the rifle with the three makes of cartridges, despite the fact that the barrel was a heavy No. 3. This also indicates the futility of having fixed sights. Sights adjusted and then fixed for one make of ammunition will not be correct for other makes except by sheer luck.

Resting the Rifle. It is believed that the following tests were among the first undertaken to determine the effect on location of center of impact of resting the rifle in various ways. Previously it was of course known generally that a rifle would center its bullets

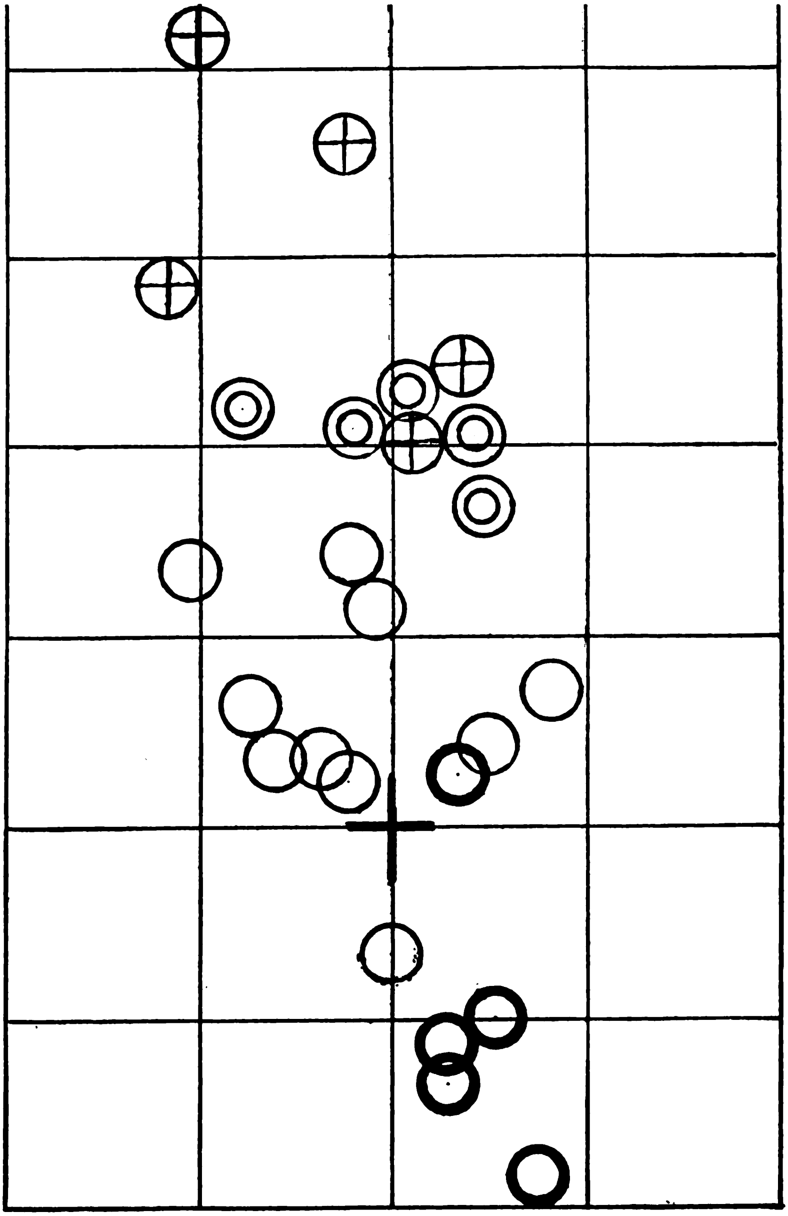


FIGURE 58

Rest test, 100 yards, .30-40 Winchester Single Shot rifle. All shots fired with same point of aim (large cross) and same sight adjustment. Squares are one inch. Light circle bullet holes fired with padded forearm rest, double circles with padded rest 4 inches in rear of muzzle, circles with cross hard rest 4 inches from muzzle, heavy circles prone with gunsling.

much higher if the barrel were rested on a solid object such as a rock or log, than if it were fired offhand.

The first test was conducted March 14, 1914 with .30-40 Winchester Single Shot Rifle, 27 inch No. 3 round barrel (same rifle as used in the preceding worn muzzle test, but with the barrel cut off three inches, and muzzle trued up). Rifle had normal factory forearm secured to the barrel by one screw at its center, and the gunsling was attached by a swivel to the tip of the forearm. Winchester A-5 scope. Winchester 220 grain soft point factory cartridges, 1914.

First group, see Figure 58 Light circles. 10 shots, bench rest, middle of forearm rested on folded blanket which gives the same results as when firing offhand. Group measures 2.4 inches, and centered .75-inch above, and .30-inch to the left of the point of aim which is indicated by the heavy cross. The squares in Figure 58 are one inch.

Second group, bench rest, resting the barrel 4 inches from the muzzle on a folded blanket. Group of five shots measures 1.5 inches, and is two inches directly above point of aim. Double circles.

Third group, 5 shots, bench rest, resting barrel 4 inches from muzzle on a 2-inch wide plank. Group measures 2.3 inches and centers 3 inches above and .30-inch to the left of the point of aim. Circles with cross.

Fourth group, 5 shots, prone with gunsling, group measures 2.23 inches and centers .75-inch below and .60-inch to the right of the point of aim. Heavy circles.

All groups were included in a rectangle 6.2 inches high and 2.3 inches wide. All were fired with the same sight adjustment and point of aim.

Remarks: If we take the offhand (padded forearm) group as standard for comparison, then with padded muzzle rest the rifle shot 1.25″ high and .30″ to the right; with hard muzzle rest it shot 2.25 inches high and in perfect line; prone with the gunsling it shot 1.5″ low and .90-inch to the right.

"I intended to try reduced loads also, but after firing the above full charged loads, and on attempting to clean the bore, a patch was pushed into the bore when it was dry and hot from firing. This patch and the rod got stuck in the bore, and it was not possible to get it out until I reached home. I then at once poured nitro-solvent into the breech and muzzle, then cleaned the bore from each end with oil, when the obstruction was easily removed by pushing out the patch and rod tip from the muzzle."

The second test was also conducted on March 14, 1914 at 100 yards, with a .30-40 Krag Jorgensen Sporting Rifle. This rifle had a

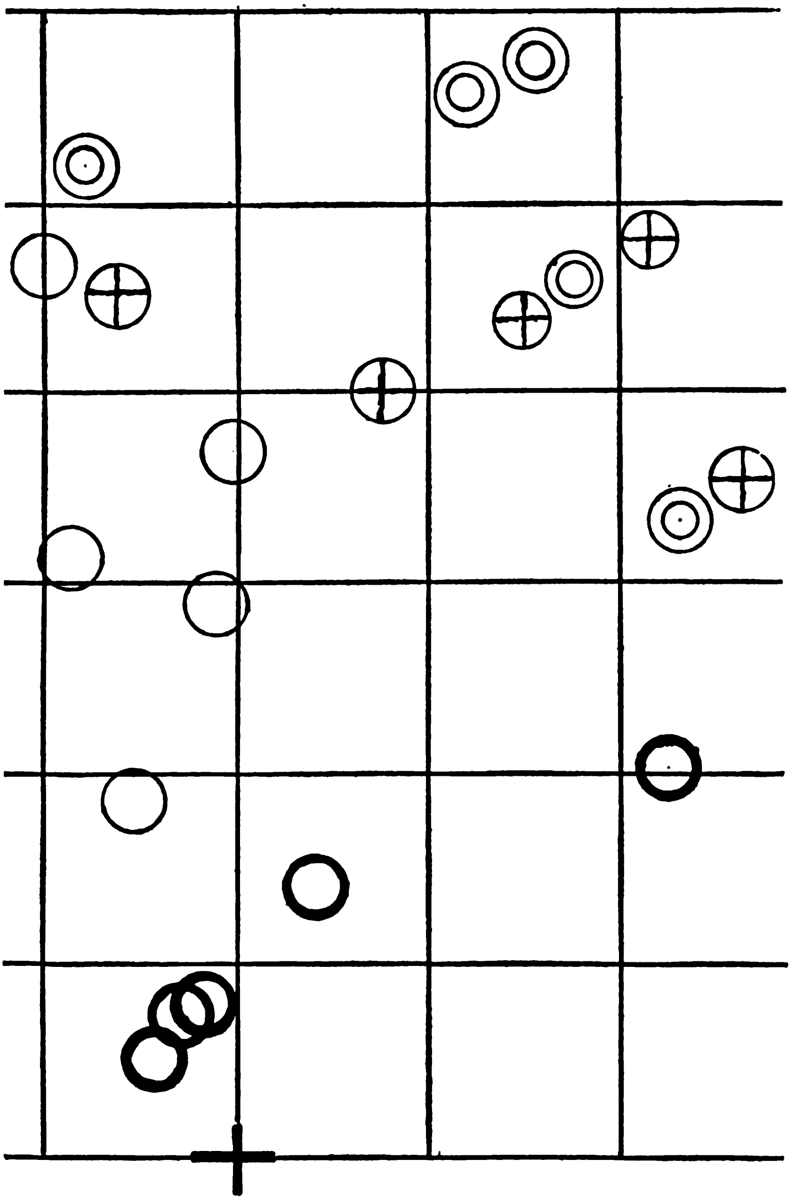


FIGURE 59

Rest test, 100 yards, .30-40 Krag Jorgensen (U.S.M. 1898) Sporting Rifle. Same details as in Figure 58.

Winchester barrel, 26 inches, round, of exactly the same shape and weight as the standard .30-40 Winchester barrel on their Model 1895 rifle, a heavy barrel at the breech, tapering to small diameter at muzzle. It was sighted with Lyman No. 48 receiver sight and gold bead front sight, the latter smoked black. The stock was of sporting type with short forearm. A steel barrel band encircled both forearm and barrel at about 2 inches in rear of forearm tip. Except when shooting prone with gunsling the barrel was practically "free floating" in the forearm. The ammunition as before was Winchester 220 grain soft point factory, 1914. All shooting was at 100 yards, same sight adjustment and point of aim throughout, heavy cross shows point of aim, and squares are one inch. See Figure 59.

First group, light circles, 5 shots, bench rest, center of forearm rested on folded blanket (giving same center of impact as offhand). Group measures 2.88-inch and centered 3.5 inches above and .50-inch to the right of point of aim.

Second group, double circles, 5 shots, bench rest, muzzle rested on folded blanket 4 inches from muzzle. Group measures 3.5 inches, and centered 4.75 inches above and 1.2 inches to the right of the point of aim.

Third group, circles with cross, 5 shots, bench rest, barrel rested 4 inches from muzzle on plank 2 inches wide. Group measures 3.13 inches and centers 4.1 inches above, and 1.3 inches to the right of the point of aim.

Fourth group, heavy circles, 5 shots prone with gunsling. Group measures 2.95 inches and centers 1.5 inches above and .40-inch to the right of the point of aim.

Summary: The effect of the various rests was thus approximately the same as with the Winchester Single Shot rifle. As compared with the offhand (padded forearm) shooting, the harder the rest, and the further towards the muzzle the rest is, the higher the rifle groups its shots; and prone with gunsling the rifle groups its shots lower than when fired offhand. But notice the much greater horizontal dispersion of this Krag rifle than with the Winchester. Possibly the one locking lug of the Krag, located at the front and bottom of the bolt, produces a horizontal as well as vertical jump, as compared with the much more uniformly supported breech block of the Winchester rifle.

The accuracy of the two rifles cannot properly be compared, because the Winchester was shot with a telescope sight while the Krag was aimed with iron (Lyman) sights.

Resting the Springfield Service Rifle. On August 28, 1919 Captain J. M. H. Wallace of the Infantry School of Arms and the writer made a rest test, almost exactly the same as the two foregoing tests, with a Springfield Service Rifle (U.S. Rifle, Cal. .30, Model 1903)

Service sights, 1919 National Match Ammunition, 100 yards. Rifle was fired by both shooters prone with gunsling, with a padded forearm rest, and with the upper band of rifle rested on a heavy log. Sight adjustment and point of aim for all shots the same. There was no marked tendency for the shots fired in any of these three ways to differ materially in the location of their center of impact. The

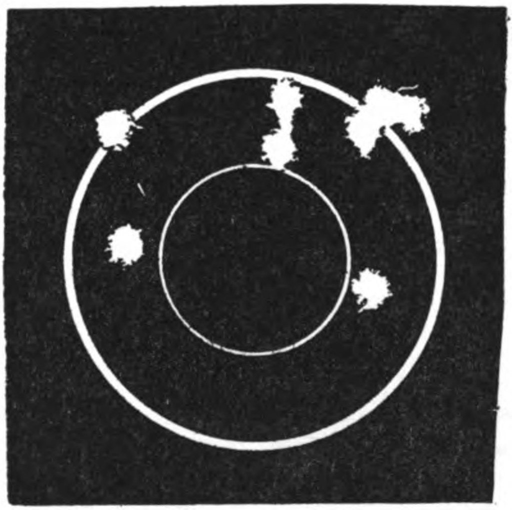


FIGURE 60

Eight shots at 200 yards, bench rest, measuring 1.6 inches. Fired with .257 Niedner-Roberts heavy barrel rifle, 100 grain Barnes Bullet, 39 grains of du Pont No. 4320 powder, and Winchester No. 120 primer. Ten power Lyman Targetspot scope. Elevation 176 half minutes, windage 121 half minutes (abbreviated E176W121). Had the firing been done for score, instead of group, the elevation would have been lowered a half minute after the first two or three shots, and all the bullets would have struck in the 10-ring, really the X-ring on a 200 yard target.

This group is so small that the writer thinks it probably is a lucky group. He had but ten of these bullets, and two were used for sighting shots on another target. But the bullet does show splendid promise. More bullets not obtainable, due to the war.

composite of all groups fired by Captain Wallace measured 6.5 inches, and for the writer 7.1 inches. Disregarding the widest shot fired by each shooter; in 3.6 and 5.5 inches.

The reason why this rifle is not sensitive to various ways of resting and firing it is because the barrel is practically free floating, (or intended to be) within its long military fore-end and hand guard. Although the fore-end was rested differently, the barrel within it was free to jump and vibrate the same in all firing positions.

Variations in Weight of Powder and Bullets. Tests conducted by the writer at Frankford Arsenal, 1921. When charges for the .30-1906 cartridge are thrown by the measure of the regular loading machines at Frankford Arsenal the maximum variation of the charge in weight is .7 grain, although it is seldom that charges vary more than .3 grain, that is 1.5 grain plus or minus from standard.

Two lots of cartridges were loaded, one with 46.4 grains, the other with 47.1 grains of Pyro D.G. powder, Lot 1407. These charges were hand weighed. The bullets, pointed, flat base, gilding metal jackets, were selected by weight and weighed just 170 grains. Each target contained five shots from each lot of cartridges, fired alternately, that is one shot with the light charge, followed by one shot with the heavy charge, at 600 yards from machine rest in a U.S. Rifle, Caliber .30, M 1906, the groove diameter of which was .308-inch. Six targets of ten shots were fired, 60 rounds in all, 30 rounds with light charge and 30 rounds with heavy charge. They show that an increase of .7 grain in the powder charge causes the bullet to strike on an average 5.90 inches high at 600 yards, as compared with the lighter charge.

An inspection of the regular run of commercial jacketed bullets shows that they sometimes vary as much as one grain in weight. Two lots of cartridges were loaded, the powder charge in each case being 46.8 grains (weighed) of Pyro D.G. powder, Lot 1407. The first lot contained bullets that weighed 170 grains, plus or minus .1 grain. The second lot contained bullets that weighed just 171 grains. All bullets were calibrated so as to be of the same diameter within .0001 inch. Six targets of ten shots each were fired at 600 yards, machine rest, from above rifle. Each target contained five shots with each lot of cartridges, fired alternately. The center of impact of the heavier bullets averaged 1.5 inches higher than that of the lighter bullet.

Experiments with Solid Gilding Metal Bullets. Conducted by the writer at Frankford Arsenal, October 11, 1921. Thirty caliber boat tail bullets of solid gilding metal (90-10) were made by turning on a lathe. The bullets were most carefully turned so as to be practically perfect. Excellent ball sized cases were used. Powder was carefully hand weighed.

The first bullets weighed 156 grains. They had the service profile of point, a one-caliber bearing of .3085-inch, and a boat tail one caliber long with nine degree taper. At the rear end of the bearing the diameter of the bullet dropped abruptly with a sharp gas check shoulder of .01-inch. Fifty grains of du Pont EX 1076 powder gave an instrumental velocity of 2830 f.s., with a pressure of 54,250 pounds using uncompressed coppers. 48 grains of the same powder gave 2720 f.s. and 52,300 pounds. 47.5 grains gave 2710 f.s. and

48,350 pounds. The last charge was adopted and the cartridges fired for accuracy at 600 yards from heavy Mann barrel, groove diameter .308-inch, held in Mann "V" rest, with the following results:

	Mean Radius	*Mean Vert. Deviation*	*Mean Horiz. Deviation*	*Extreme Vert.*	*Extreme Horiz.*
10 shots	4.52"	3.30"	2.32"	15.90"	8.95"
10 shots	5.70	4.26	3.30	16.65	13.10
Average	5.11	3.78	2.81	16.27	11.02

The second lot of bullets weighed 160 grains, also turned from solid gilding metal. They were an exact copy of the 180 grain 1921 boat tail bullets manufactured by the Western Cartridge Company, maximum diameter .3085-inch. Powder charge 49 grains of du Pont EX 1076 powder giving an instrumental velocity of 2721 f.s. and a pressure of 53,670 pounds with uncompressed coppers. The firing was at 600 yards with Mann barrel exactly as above, and the results were:

	Mean Radius	*Mean Vert. Deviation*	*Mean Horiz. Deviation*	*Extreme Vert.*	*Extreme Horiz.*
10 shots	4.04"	2.00"	3.52"	6.25"	13.50"
10 shots	5.98	4.50	3.60	21.20	13.20
Average	5.01	3.25	3.56	13.72	13.35

The firing of both bullets was done on a calm day, and the utmost care was taken in every respect. These near perfect solid gilding metal bullets shot with only mediocre accuracy.

Test of .505 Gibbs Magnum, British Elephant Rifle. December 1921. Rifle the property of Ralph H. White, Esq. Rifle built by George Gibbs, Bristol, England, and cartridges furnished by Gibbs. Magnum Mauser breech action. Sporting stock. British open sights.

Weight of rifle	10.5 pounds
Length of barrel	26 inches
Weight of bullet	526.8 grains
Diameter of bullet	.506 inch
Jacket, cupro nickel, soft point.	

Length of case	3.13 inches
Length of cartridge	3.70 inches
Diam. head of case	.634" to .638"
Normal charge, Cordite	90 grains
Advertised velocity	2350 f.s.
Actual velocity (F.A.)	2135 f.s. at 78 feet

Note: These cartridges which came with the rifle were undoubtedly loaded for use in tropical countries. Cordite loaded to give velocities around 2150 f.s. in temperate climates will probably give about 200 f.s. higher velocity in the tropics, so that the advertised velocity is probably approximately correct.

Using the cartridges imported with the rifle, it was shot at 100 yards. Shooting was done sitting at a bench, elbows rested on bench, but rifle not rested. Two five-shot groups were fired, each in approximately five inches, and each group well on the point of aim. The recoil was heavy, very heavy, but not damaging. During the last five shots the recoil gave considerable shock to the nervous system. Barrel became quite hot.

Using primed cases and bullets imported by Mr. White a charge of du Pont EX 1076 nitrocellulose powder was developed.

70	grains	gave	1720 f.s.
95	"	"	2091 "
100	"	"	2175 "
100	"	"	2175 "
100	"	"	2184 "

With the 100 grain charge an accuracy test was then made at 100 yards as above, with practically identical results. From examination of primers and fired cases it was estimated that the pressure was slightly less than with the Cordite cartridges that came with the rifle.

Comments. It is exceedingly difficult to get good accuracy with open rear sight, and when apprehensive of a heavy recoil. The rifle will undoubtedly shoot better than 5 inch groups at 100 yards, if fitted with better sights. At any rate the accuracy is ample for heavy and dangerous African and Indian game.

The writer has from time to time examined and fired a large number of best quality rifles by all the leading British makers. Almost all of them required a great amount of adjustment before they could be considered suitable for field work with the ammunition that was imported with them. On most the sight adjustment was not correct, the bolt did not operate smoothly, and the trigger pull required smoothing up. This .505 Gibbs rifle was the first the writer had worked with which required absolutely no change, alter-

ation, or adjustment, although the writer would have preferred to have it fitted with a Lyman type aperture rear sight. As received from its maker it was in perfect shape to be taken immediately on a long shooting trip.

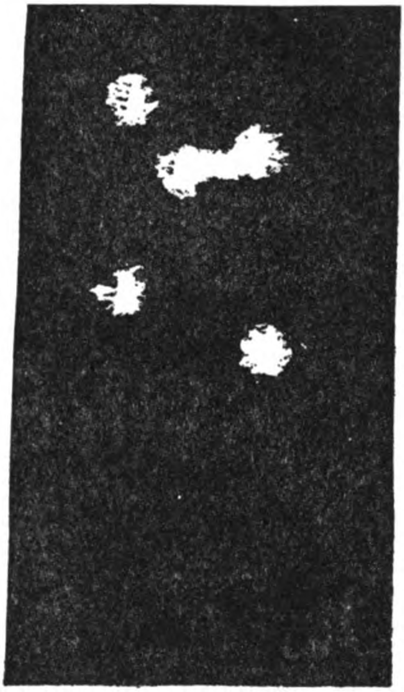


FIGURE 61

This five shot group was fired at 100 yards to obtain the height of trajectory above the line of aim at that distance when sights were set for 200 yards. The rifle was a .30-06 Sporting Springfield with Zeiss Zielklein 2¼ power scope with flat top post reticule. Aim was taken with the post just touching the bottom of the black of the inverted "T" target, a target often used for test purposes.

The load, a most accurate one, was the 172 grain Western Tool & Copper Works open point bullet, 50 grains of du Pont No. 4320 powder, and the F.A. No. 70 primer, M.V. about 2750 f.s. (Such a load would have been unsafe with modern non-corrosive non-mercuric primers.) The group is centered 2½ inches above the point of aim and measures 1.48 inches. Therefore, with this sight adjustment the bullets average striking 2½ inches above the point of aim at 100 yards, and on the point of aim at 200 yards.

Test of Swiss Army Rifle. Rifle and ammunition furnished by Captain F. Muller Hurst. Rifle is of the straight pull type Schmidt-Rubin, with detachable, vertical box magazine holding six rounds. It weighs 9 pounds, and the barrel is 30.8 inches long. The barrel is

rifled with four grooves and lands, the grooves being approximately twice the width of the lands which are .075-inch wide. Groove diameter .3070-inch, twist one turn in eleven inches.

The cartridge is a rimless, 3.05 inches long, and weighs 390 grains. The bullet is of boat tail type, without a cylindrical bearing, weighs 174 grains, and the maximum diameter is .3073-inch. The charge was 49.2 grains of a square cut flake powder. Three shots fired for velocity gave an average of 2675 f.s. at 78 feet, with an extreme variation of 41 feet. The cartridges were packed in paper cartons of ten rounds, and the cartons were labeled "Cal. 7.5 M/M, Ord. 1911."

The accuracy test fired at 600 yards was rather poor because the rifle being full stocked to within three inches of the muzzle could not be clamped in the Frankford rest in a satisfactorily rigid manner.

Accuracy at 600 yards

Groove Diam.	*M.R.*	*M.V.D.*	*M.H.D.*	*E.V.*	*E.H.*	
19.75″	8.85″	6.04″	5.40″	18.75″	19.70″	
30.20	7.08	5.02	4.60	25.15	20.30	
18.85	5.77	5.07	1.98	18.50	10.60	
22.93	7.23	5.37	3.99	20.80	16.86	Mean.

Making a Sulphur Cast of Chamber. It is sometimes desired to obtain the dimensions and shape of the chamber, bullet seat, and bore of an unknown rifle. This can be done by making a non-shrink sulphur cast of the chamber, and measuring the cast. The following is the best procedure:

Take a stiff wire about .06-inch in diameter, and a rubber cork the size of the bore of the rifle. Drill a hole in the exact center of the cork so the wire can be inserted tight therein, cork at one end (the forward end) of the wire. Enter the cork and wire into the chamber, and press the cork into the bore to the point to which the cast is to extend, usually about one-half inch in front of chamber. The wire is to function as a handle for the cast, and should be sufficiently long for this purpose, extending several inches to the rear beyond the chamber. The chamber and that portion of the bore of which it is desired to make the cast should be thoroughly cleaned and should have a very slight film of thin oil.

The mixture is made as follows:

Sulphur............................	2 ounces
Powdered lampblack................	3 grains
Gum camphor dissolved in alcohol....	3 drops

Heat *very slowly* and stir continually. If not stirred very slowly the mixture will become too thick. When it arrives at a thin pouring condition pour it into the chamber from the breech end until it completely fills the chamber, and allow it to cool thoroughly. When it is cold remove the cast by inserting a cleaning rod at the muzzle and push the cork and cast out very gently, catching and guiding the cast by the wire. Handle and measure the cast gingerly for it is quite brittle. This mixture does not shrink after cooling, whereas the plain sulphur cast shrinks approximately .002-inch.

Further Notes on Killing Power. A rifleman or sportsman can determine the ballistic value of a rifle and cartridge from tests and target practice, but he can assure himself of the killing power of a certain cartridge only by personal experience on game, or by the study of the best books. Information gained from reading magazine articles is liable to be misleading unless the reader has had sufficient experience to enable him to judge the worth of the article. A magazine article is so short that it cannot possibly cover more than one small phase of a subject. Then too a magazine editor is rather prone to accept and publish a certain article because it has reader interest, and he is not always in a position to determine its technical correctness or the experience of its author. The two instances which follow illustrate this.

The New York Sun published an article on December 19, 1893 from which the following is extracted:

> As to the Winchester .45-90; I have with this weapon killed four rhinoceros, two with a single shot at 100 yards, and two while charging—one with four and one with five shots. I have known a rhino taking nine hardened .577 bullets and getting away. With the Winchester I have killed eight giraffe, shooting all but one of them in the neck, with a single shot at distances varying from 150 to 200 yards. I have with the same weapon killed many zebra, oryx, beisa, eland, and other antelope at distances varying from 100 to 500 yards. . . . In the case which occurred the rhino . . . after smashing several boxes, dashed after another man, and was only prevented from killing him by a lucky Winchester shot which broke his shoulder.
>
> WILLIAM ASTOR CHANDLER

Now the writer does not for a moment doubt the personal experience of Mr. Chandler with this rifle and cartridge, but there are other remarks in the quotation which are misleading, and which indicate that Mr. Chandler was not well informed on rifles in general. If Mr. Chandler really killed an antelope at 500 yards (how did he measure it?) with the .45-90 old Father Luck certainly had him by the hand.

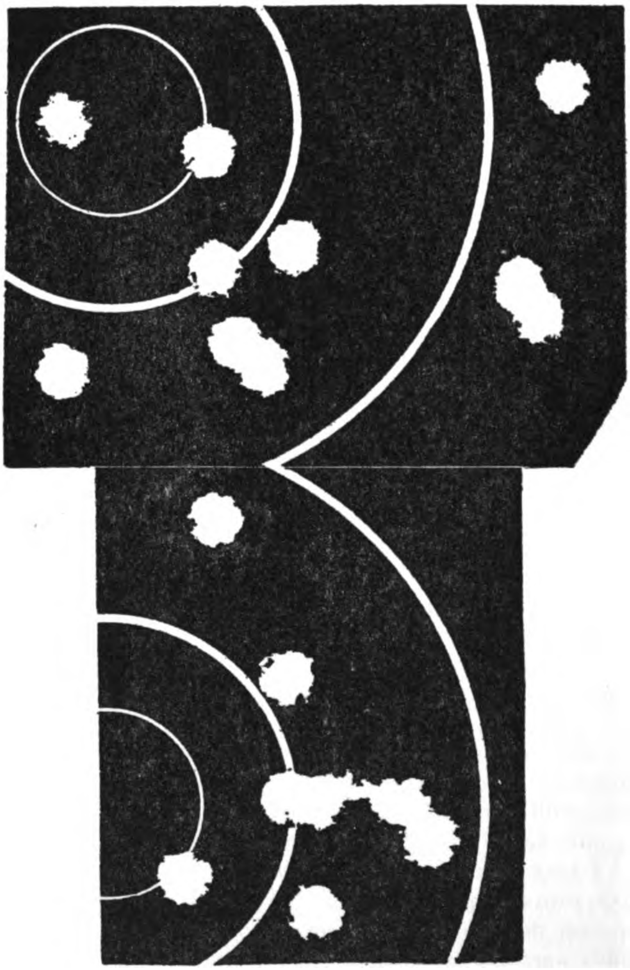


FIGURE 62

These two groups, ten shots on the top and eight shots on the bottom, were fired consecutively from a .30-06 Springfield sporting rifle equipped with a Zeiss Zielklein 2¼ power scope with flat top post reticule. The shooting was at 100 yards from bench rest. The load was the Winchester 180 grain Silvertip 1941 factory cartridge. The groups measure 2.7 and 2.1 inches, and are representative of the fine accuracy now obtained with recent Winchester, Remington, and Western sporting ammunition. A few years ago most sporting ammunition gave much larger groups. In the top group the lower, right hand bullet hole was made by the first shot from a clean, cold bore.

The low power hunting scope used has an error of aim of about one-quarter minute on a bullseye target. Had a higher power target scope with cross hairs been used, both groups would have been a quarter to a half inch smaller.

Sportsmen who have had *ten* or more years of *continuous* experience in shooting African game, and there were many such, unhesitatingly condemn such a charge as a .45 caliber bullet of 300 grains, backed by 90 grains of American F.G. black powder—the .45-90 load. They do concede that a .45 caliber 350 grain bullet backed by 90 grains of Curtis and Harvey No. 6 powder (English black powder equal to 120 grains of American F.G. Black) is satisfactory for *soft skinned* African game, but that is a horse of another color.

The reference to the .577 rifle is unfortunate. The cartridge for that rifle was loaded with six drams of Curtis and Harvey No. 6 powder and a 650 grain bullet. It was an exceedingly effective cartridge in its day, alike on soft skinned and thick skinned dangerous game, perhaps the heaviest black powder cartridge that was not too powerful and had sufficient accuracy for successful use on African antelope. It was used by great numbers of African and Indian hunters, and particularly Sir Samuel Baker (with Speake one of the co-discoverers of the source of the Nile) and Arthur H. Neumann (the most experienced elephant hunter who ever lived), used the .577 for both light and heavy African game for many years, always with deadly results. No more experienced hunters than these have lived since their day.

The other example which the writer thinks it interesting to present was occasioned by certain writings by an American hunter in Africa, and comments on them in a letter written by Stewart Edward White, the well known author and very experienced hunter, to the late Captain Edward C. Crossman.

An American, Charles Cotter, had gone to British East Africa, and after some experience there had set himself up as a professional hunter. He wrote a number of articles that were published in American magazines, in the course of which he stated that the .32 Special, and afterwards the .250-3000 cartridges had ample killing power for any African game—or words to that effect. It was these articles, and certain advertisements which resulted from them, that prompted Mr. White to write the following letter which the writer quotes in full:

March 18, 1920

Dear Crossman:

Your letter came to me here at Sandyland—my beach place near Carpinteria. There seems to be an awful lot of bunk about this small caliber, light bullet stuff. I am not competent to discuss this particular weapon because I have never tried it, but it does not differ from others of the same general type. Nor can I discuss Cotter for I do not know him. But I do know African game. You can kill any animal

with anything if you hit him in just the right place. I know of a 400 pound bear being killed dead with a .22 Short. But that does not mean that a man is justified in going after bear with a .22, either from the point of view of the bear or himself. As to the various sorts of game mentioned in the Company's advertisement: I do not doubt that any of them can be killed with the .250-3000. But with the possible exception of lion and leopard, I do not believe any of them can be regularly killed with it, nor under any but the most carefully arranged and lucky circumstances. The rhino has been experimented with with all sorts of weapons. I would refer you to Roosevelt's "African Game Trails" for a very typical killing of a rhino with the Springfield. The hippo can be killed by a properly placed bullet at a certain place at the back of the skull, and at that point most any old bullet will do; but at any other point only a hard nose of great weight and penetration will do. The buffalo is a solid muscled, thick skinned animal that requires deep penetration and a hell of a lot of shock to even worry. The blow struck by a .465 Holland, the bullet from which remains in the beast, does the trick only when properly placed. A light bullet, no matter what its velocity, has on the average small effect on the slow nervous system of this animal. As to elephant, there is one spot where any solid jacketed bullet will kill, but there is no spot on an elephant where a soft point bullet that mushrooms or goes to pieces will surely kill, or surely seriously affect. I mentioned lions and leopards as a possible exception because I know nothing about the effect of this bullet on soft skinned game. But this I will say: unless both Mr. Cotter and the Company know that its record in the former's hands was due not so much to a cool man properly placing his shots, as to the superior power of the cartridge itself, they are not justified in urging it as a lion gun. You can kill lions with light guns. I have killed seven with the Springfield. But things have got to go just exactly right. It is better to take a heavier gun for such game, and then if things do not go just exactly right you've got a margin of safety. It seems to me that it would be criminal to advertise this gun for exceedingly dangerous game without more knowledge than can be gained by the experience of one man; who was, moreover, trying to collect instances favorable for such advertising. I cannot but remember that Mr. Cotter went to Africa with the advertised statement that the .32 Special was big enough for anything, a manifestly ignorant and absurd statement. I also know that arms manufacturers give especial arms and ammunition in hope of being able to advertise in some such fashion. I believe in trying new things; but I cannot endorse leading sportsmen to believe and place their trust in what is still experimental when it is a case of dangerous game. And then too we ought to be fair to the game.

I don't mind your using my name, providing you use all of the preceding page. I have a horror of half quotations of a man's attitude, as so many misconceptions always arise from it.

As ever,
S. E. W.

On his return from Africa in 1925, having had experience with modern bullets in his .30-06 Springfield, Mr. White wrote as follows: "Might say that I have killed 36 lions with the Springfield and 37 with the .405, and would now leave the latter home, provided I had the 220 Western bullet."

(Note: This was the 220 grain soft point bullet with just a pinpoint of lead exposed at the tip, made by the Western Cartridge Company. It is not known if it was the 220 grain soft point, boat tail bullet, or the earlier type with flat base. The two are identical except for the base. Muzzle velocity was 2300 f.s.—T. W.)

Some Interesting Chronology

The first issue of "The Rifle," (the forerunner of "Shooting and Fishing,"—"Arms and the Man," and the present "The American Rifleman,") was in May 1885. It was published monthly by A. C. Gould at 4 Exchange Place, Boston, Mass. Before its publication there had been only desultory discussion of rifles and ammunition in the American press. Prior to the above date practically everything of value is contained in the anual reports of The Chief of Ordnance, United States Army.

There had been many small books published before this on muzzle loading rifles, but so far as the writer knows the only one fairly free from conjecture and inaccuracies, and that indicated real experience on the part of its author was: "Instructions to Young Marksmen as exhibited in the Improved American Rifle," by John R. Chapman, published in 1848.

Mr. J. F. Rabbeth was the originator of the rifleman's "score book," which introduced the first systematic method of recording ballistic data. It was suggested by him in September 1886.

Despite what we read about the popularity of the Ballard and other rifles in the Old West, a very prominent hunter and rifleman wrote from Montana in June, 1888: "Without a doubt the .45-60 Winchester Model 1876 repeater is the favorite hunting piece in use in this section of the West. The Winchester Model 1886 rifle is practically unknown in Montana. I have never seen a Ballard, Remington, or Maynard in use, and the .32 and .35 calibers are never met with here."

The first soft point, jacketed bullets (s.f.a.k.) were produced in

the spring of 1890 for the .303 British service rifle by the Lorenz Ordnance and Ammunition Company of Millwall, London.

The first American commercial, high power, smokeless sporting rifle was the Winchester Single Shot for the .30-40 Krag cartridge, first advertised April 26, 1894.

The Winchester Model 1894 rifle was first manufactured for the .32-40 and .38-55 black powder cartridges. It was not advertised in .30 W.C.F. (.30-30) caliber until May 16, 1895.

The Winchester Model 1895 rifle was first advertised March 26, 1896 and only for the .38-72 and .40-72 black powder cartridges. Some months later it was adapted to the 6 mm Lee-Navy and the .30-40 Krag cartridges, and could be had with pistol grip as well as straight grip. About a year later the breech action was modified to include a finger lever lock to strengthen it, and the sides of the receiver were bevelled. After this modification the rifle could be had only with straight grip stock. The .40-72 Winchester Model 1895 rifle of the writer's has the modified breech action, but the pistol grip stock was custom built. This in view of many questions the writer has received on this subject.

The .25-36 Marlin rifle was first advertised June 6, 1895, and the .303 Savage rifle on June 13, 1895. The Savage breech action was slightly modified in 1899.

APPENDIX

1 THE MINUTE AND THE MIL.
2 MATHEMATICAL REMINDERS.
3 GROOVE DIAMETER AND TWIST—RIFLES.
4 GROOVE DIAMETER AND TWIST—PISTOLS
5 ANGLES OF ELEVATION.
6 BALLISTIC TABLES, .45-70 SPRINGFIELD RIFLE AND CARBINE
7 BALLISTIC TABLES, .30-40 KRAG RIFLE AND CARBINE
8 BALLISTIC TABLES, .30-06 SPRINGFIELD RIFLE.
9 BALLISTIC TABLES, WINCHESTER CARTRIDGES, 1907
10 BALLISTIC TABLES, WINCHESTER CARTRIDGES, 1941
11 TABLE OF SHOT SIZES, UNITED STATES.
12 TABLE OF SHOT SIZES, BRITISH.
13 RECOIL OF 12 GAUGE SHOTGUNS.
14 BALLISTICS OF LOW POWER WEAPONS
15 BALLISTIC TABLES, .303 BRITISH LEE ENFIELD

1

THE MINUTE AND THE MIL

The Minute of Angle

The value of an angle may be expressed in degrees, minutes, and seconds. There are 360 degrees in a circle, and 90 degrees in a right angle. One degree equals 60 minutes. If we prolong the sides of an angle of one minute for 100 yards, the two lines at 100 yards will be 1.047-inches apart. That is an arc of one minute on a radius of 100 yards subtends 1.047-inches. For convenience we assume that a minute subtends one inch per hundred yards, thus:

1	minute	equals	.50	inch	at	50 yards.
1	"	"	1.00	"	"	100 "
1	"	"	2.00	"	"	200 "
1	"	"	5.00	"	"	500 "

and so on.

In Small Arms Ballistics and Rifle Marksmanship all angles of elevation, azimuth (windage) and dispersion are given in terms of degrees and minutes, and all modern rifle sights are graduated in minutes or in fractions thereof.

In plain terms to be remembered; **"One minute equals one inch per hundred yards."**

The Mil

In the United States Army, in all matters of fire control (except only marksmanship problems with the shoulder rifle) the unit of angular measurement is the Mil instead of degrees, minutes, and seconds. Thus fire control tables, including pertaining angles of elevation, used chiefly in conjunction with machine guns and artillery, are given in terms of Mils.

A mil is the angle subtended by an arc of one unit on a radius of 1,000 units, or, in other words, an angle the tangent of which is approximately 1/1,000. The arbitrary value of the mil adopted by the United States Army is 1/6,400 of a circle. The conversion factors are;

17.8 mils equal 1 degree
1 mil equals 3 minutes, 22 seconds.

To convert mils to minutes, multiply by 3.375

In plain terms to be remembered; **"A Mil is 1/1,000 of the range."**

2
MATHEMATICAL REMINDERS

Linear Measure

12 inches	= 1 foot	3600 inches	= 100 yards.
3 feet	= 1 yard	1 cubit	= 2 feet
2 yards	= 1 fathom	1 pace	= 3 feet
16½ feet	= 1 rod	1 palm	= 3 inches
4 rods	= 1 chain.	1 hand	= 4 inches
10 chains	= 1 furlong	1 span	= 10⅞ inches.
8 furlongs	= 1 mile	⅛ inch	= .125-inch
3 miles	= 1 league	1/16 inch	= .0625-inch
1,760 yards	= 1 mile	1/32-inch	= .0312-inch
5,280 feet	= 1 mile	1/64 inch	= .0156-inch

Avoirdupois Weight

16 drams	= 1 ounce (oz.)	7,000 grains	= 1 pound
16 ounces	= 1 pound (lb.)	437.5 grains	= 1 ounce
25 pounds	= 1 quarter	27.34 grains	= 1 dram
4 quarters	= 1 hundred		
20 hundreds	= 1 ton		
1 ton	= 2,000 lbs.		

Metric System—Length

10 millimeters (mm) = 1 centimeter = 0.3937 inches
10 centimeters (cm) = 1 decimeter = 3.937 inches
10 decimeters (dm) = 1 meter (M) = 39.37 inches.

1 millimeter	= .03937-inch	6 millimeters	= .23622-inch
2 "	= .07874 "	7 "	= .27559 "
3 "	= .11811 "	8 "	= .31496 "
4 "	= .15748 "	9 "	= .35433 "
5 "	= .19685 "	10 "	= .39370 "

Metric System—Weight

10 milligrams (mg)	= 1 centigram (cg)	1 gram	= .0527 ounce
10 centigrams	= 1 decigram (dg)	1 kilogram	= 2.2046 lbs.
10 decigrams	= 1 gram (g)	1 metric ton	= 1.023 Eng. Tons
10 grams	= 1 dekagram (Dg)	1 ounce	= 28.35 grams
10 dekagrams	= 1 hektogram (hg)	1 pound	= .4536 kg.
10 hektograms	= 1 kilogram (kg)		

To find Circumference:
Multiply diameter by 3.1416
Or divide diameter by .3183

To find Diameter:
Multiply circumference by .3188
Or divide circumference by 3.1416

To find Area:
Multiply circumference by one-quarter of the diameter.
Or multiply the square of the diameter by .7854
Or multiply the square of the circumference by .07958
Or multiply the square of one-half the diameter by 3.1416

To find Side of a square of Equal Area:
Multiply diameter by .8862
Or divide diameter by 1.1284
Or multiply circumference by .2821
Or divide circumference by 3.545

To find Area of an Ellipse:
Multiply the product of its axes by .7854

To find Contents of a Cylinder:
Multiply area of end by length.

To find Surface of a Cylinder:
Multiply the length by the circumference plus area of both ends.

To find Surface of a Sphere:
Square the diameter and multiply by 3.1416

To find Contents of a Sphere:
Multiply diameter cubed by .5236

To find Sectional Density (of a bullet)
Divide weight (in pounds) by square of diameter in inches.

Care in Using Right Units:
In performing all calculations care is required to see that the correct units are used. If the result is to be in pounds—grains and ounces must be reduced to pounds throughout. If in feet—inches and yards must be reduced to feet.

Appendix

3

GROOVE DIAMETERS & TWIST OF RIFLING OF AMERICAN RIFLES

Caliber and Cartridge	*Make*	*Groove Diameter Inches*		*Twist of Rifling. No. of Inches per Turn*
		Min.	*Max.*	
.218 Bee	Winchester	.224	.2245	16
.219 Zipper	Winchester	.224	.2245	16
.22 Hornet	Win. & Sav.	.222	.223	16
.22 Hornet	Stevens	.223	.224	16
.22 Short, R.F.	Winchester	.224		20
.22 Short, R.F.	Stevens	.223	.224	25
.22 Short, R.F. Auto	Remington	.218	.220	24
.22 Short (Manually Operated)	Remington	.222	.224	16
.22 Long Rifle, R.F.	Winchester	.222	.2228	16
.22 Long Rifle, R.F.	Stevens	.223	.224	16
.22 Long Rifle, R.F.	Remington	.222	.224	16
.22 W.R.F.	Winchester	.226		14
.22 W.R.F.	Stevens	.223	.224	14
.220 Swift	Winchester	.224		14
.22 Savage H.P.	Savage	.227		12
6 M/M Lee Navy	Winchester	.242	.244	7½
.25 Stevens R.F.	Stevens	.256	.257	17
.25-20 S.S. & W.C.F.	Winchester	.256	.2575	14
.25-20 S.S. & W.C.F.	Stevens	.256	.257	13
.25-20 S.S. & W.C.F.	Savage	.256		14
.25-35 W.C.F.	Winchester	.256	.2575	8
.25-36 Marlin	Marlin	.257	.2575	9
.25 Remington Auto	Remington	.256	.258	10
.25 Niedner, Spg. & Krag	Niedner	.2565	.2575	12
.250-3000 Savage	Savage	.257		14
.250-3000 Savage	Winchester	.256	.258	14
6.5 M/M Mannlicher	Austrian	.263	.264	7½
.256 Newton	Newton	.264	.265	10
.257 Roberts	Winchester	.256		10
.257 Remington-Roberts	Remington	.256	.258	10
.270 W.C.F.	Winchester	.277	.2785	10
7 M/M Mauser	German	.2854	.2874	8.66
7 M/M Mauser	American	.2845	.2855	10
.280 Ross	Ross	.289	.290	8.66

GROOVE DIAMETERS & TWIST OF RIFLING OF AMERICAN RIFLES

(Continued)

Caliber and Cartridge	*Make*	*Groove Diameter Inches*		*Twist of Rifling. No. of Inches per Turn*
		Min.	*Max.*	
.30-30 W.C.F.	Winchester	.308	.3085	12
.30-30 W.C.F.	Savage	.308		12
.30-30 W.C.F.	Stevens	.308	.309	12
.30-30 Remington Auto	Remington	.308	.3085	12
.30 Krag	U. S. Govt.	.308	.310	10
.30 Remington	Remington	.306	.308	12
.30-06 Springfield	U. S. Govt.	.308	.309	10
.30-06 Savage	Savage	.308		12
.300 Savage	Savage	.308		12
.300 H. & H. Magnum	Winchester	.308	.3085	10
.32 Short & Long R.F.	Winchester	.313	.315	20 to 26
.32 Short & Long R.F.	Stevens	.309	.310	25
.32 Rem. Auto	Remington	.319	.321	14
.32 Ideal	Stevens	.323	.324	18
.32 Win. Special	Winchester	.320	.3205	16
.32 Win. Self-Loading	Winchester	.320		16
.32-20 W.C.F.	Winchester	.311	.3115	20
.32-20 W.C.F.	Stevens	.310	.311	20
.32-20 W.C.F.	Savage	.3105		20
.32-40, B & M	Winchester	.320	.3205	16
8 m/m Mauser	German	.318	.326	9 to 10
.303 British	English	.312	.314	10
.303 Savage	Savage	.308		12
.33 W.C.F.	Winchester	.338	.3385	12
.348 Winchester	Winchester	.348		12
.35 Win. Self-Loading	Winchester	.351	.352	16
.351 Win. Self-Loading	Winchester	.351	.352	16
.35 Remington Auto	Remington	.357	.359	16
.35 W.C.F.	Winchester	.358	.3585	12
.35 Whelen	Griffin	.357	.3575	18
.35 Newton	Newton	.359	.359	12
.375 H. & H. Magnum	Winchester	.376	.376	12
.38 Short, Long & Ex. Long, C.L.	All	.358	.359	36

GROOVE DIAMETERS & TWIST OF RIFLING OF AMERICAN RIFLES

(Continued)

Caliber and Cartridge	*Make*	*Groove Diameter Inches*		*Twist of Rifling. No. of Inches per Turn*
		Min.	*Max.*	
.38-40 W.C.F.	Winchester	.400	.4005	36
.38-40 W.C.F.	Remington	.398	.400	36
.38-55 W., B. & M.	Winchester	.379	.3795	18
.38-56 W.C.F.	Winchester	.379	.3795	20
.38-70-255 W.C.F.	Winchester	.379	.3795	24
.38-72-275 W.C.F.	Winchester	.379	.3795	22
.38-90 W.C.F.	Winchester	.379	.3795	26
.40-50 Sharps Straight	Winchester	.403	.405	18
.40-70 S.S. and Ballard	Winchester	.403	.405	20
.40-70-330 Winchester	Winchester	.408		20
.40-72-330 Winchester	Winchester	.406	.407	22
.40-82-260 Winchester	Winchester	.408		28
.40-90 Sharps Straight	Winchester	.403	.405	18
.40-110 Winchester	Winchester	.403	.405	28
.40-60 Winchester	Winchester	.4045	.405	40
.401 Winchester S.L.	Winchester	.407	.408	14
.404 Magnum	Hoffman	.423	.424	14
.405 Winchester	Winchester	.413	.4135	14
.43 Spanish	Winchester	.439	.440	20
.44-40 W.C.F.	Winchester	.4285	.429	36
.44-40 W.C.F.	Remington	.424	.426	20
.44 Henry R.F.	Winchester	.4285	.4295	36
.45-60 W.C.F.	Winchester	.456	.458	20
.45-70 Winchester	Winchester	.456	.458	20
.45-70 U. S. Govt.	U. S. Govt.	.457	.458	22
.45-75 W.C.F.	Winchester	.456	.458	20
.45-90 W.C.F.	Winchester	.458		32
.45-125 W.C.F.	Winchester	.456	.458	36
.45 Sharps, 3¼	Sharps	.458	.459	18
.50 Sharps	Sharps	.509		
.50-95 Winchester	Winchester	.5055		60
.50-110-450 Winchester	Winchester	.506		60
.50-70 Govt.	U. S. Govt.	.515		24 to 42
.58 Govt. M.L.	U. S. Govt.	.590		68

4

GROOVE DIAMETER AND TWIST OF RIFLING OF PISTOLS

Cartridge	*Manufacturer*	*Twist in Inches*	*Standard Groove Diameter*
.22 Long Rifle	S & W	15	.2235″
.22 Colt	Colt	14	.222
.30 Mauser	German	8	.309
.30 Luger	German	9.85	.310
.32 Colt Auto	Colt	16	.311
.32 S & W	S & W	18¾	.313
.32-20	S & W	12	.312
.32 Colt	Colt	16	.312
.357 Magnum	S & W	18¾	.357
.38 S & W	S & W	18¾	.357
.38 S & W Special	S & W	18¾	.357
.38 Colt Special	Colt	16	.354
.38 Colt Auto	Colt	16	.356
.38 Colt Revolver	Colt	16	.354
.38-40 Colt	Colt	16	.402
.41 Colt	Colt	16	.402
.44-40 Colt (old models)	Colt	16	.424
.44-40 Colt (new models)	Colt	16	.427
.44 S & W	S & W	20	.431
.44 Colt	Colt	16	.427
.45 Colt Auto Pistol	Colt	16	.451
.45 Colt	Colt	16	.452

All Colt weapons have left hand twist; all others right hand.

APPENDIX

5

ANGLES OF ELEVATION

In Minutes

Rifles Zeroed at 100 Yards

Cartridge	*Bullet, Grains*	*M.V. f.s.*	*Yards*						
			200	*300*	*400*	*500*	*600*	*800*	*1,000*
.22 Hornet	46 H	2,625	2.9	7.5	19.0	31.5			
.218 Win. Bee	46 H	2,860	2.6	6.8					
.22-3,000 Lovell R2	50 S	3,000	2.3	6.5					
.219 Win. Zipper	46 H	3,390	1.9	6.0					
.219 Win. Zipper	56 H	3,050	2.2	6.6					
.220 Win. Swift	48 S	4,140	1.3	3.0	6.0	10.1			
.220 Win. Swift	55 S	3,720	1.5	3.7	6.5	11.2			
.25-20 W.C.F.	86 F	1,450	9.2	25.3					
.25-20 W.C.F. High Vel	86 F	1,710	7.7	20.7					
.25-20 W.C.F. Super Speed	60 H	2,210	5.5	16.0					
.25-35 Win.	117 R	2,280	3.7	9.2					
.250-3,000 Savage	87 S	3,000	2.5	4.5	7.0	11.5	16.0		
.250-3,000 Savage	100 H	2,790	2.9	6.0	10.0	15.0	22.0		
.257 Roberts	87 H	3,180	2.0	4.5	8.0	12.8			
.257 Roberts	100 H	2,860	2.5	5.7	9.6	14.3			
.257 Roberts	117 H	2,650	2.9	6.6	10.9	16.1			
.270 Win	100 S	3,540	1.5	3.5	6.1	9.4			
.270 Win	130 S	3,120	1.8	4.2	7.5	10.9			
.270 Win	150 R	2,770	2.5	6.0	11.0	16.3			
7 mm Mauser	150 P	2,750	2.7	5.6	8.3	13.0			
7 mm Mauser	175 R	2,460	3.0	6.0	10.5	16.0			
.30-30 W.C.F.	170 R	2,200	4.5	9.5					
.300 Savage.	150 S	2,660	2.5	5.9	9.6	14.0			
.300 Savage.	180 R	2,380	3.9	8.0	13.5				
.30-40 Krag.	180 S	2,460	3.0	6.5	11.5	15.4			
.30-40 Krag.	220 R	2,000	5.2	11.3	18.5	27.1	36.7	61.3	91.5
.30-06 U.S. 1906	150 P	2,700	2.8	5.8	9.4	13.5	18.2	30.1	45.9
.30-06 U.S. M2	150 P	2,800	2.6	5.5	9.0	13.0	17.9	29.5	45.0
.30-06 U.S.	150 P	2,960	2.0	4.7	8.0	12.2			
.30-06 U.S. M1 B.T.	172 P	2,650	2.6	5.4	8.5	11.9	15.6	24.4	35.4
.30-06 U.S.	180 P	2,700	2.5	5.5	8.5	14.3			
.30-06 U.S.	220 R	2,410	3.0	6.5	10.5	16.0	23.0		
.300 H and H Magnum	180 P	2,930	2.2	4.8	8.0	12.0			
.300 H and H Magnum	220 R	2,610	2.8	6.0	9.5	15.0			

Cartridge	*Bullet, Grains*	*M.V. f.s.*	*Yards*						
			200	*300*	*400*	*500*	*600*	*800*	*1,000*
.32-20 W.C.F.	115 F	1,280	14.5						
.32-20 Win. H.V.	115 F	1,600	10.0						
.32-20 Win Super Speed	80 F	2,050	7.5						
.32-40 W.M. & S.	165 F	1,440	10.0						
.32 Win. Special	170 F	2,260	4.5	9.5					
.33 W.C.F.	200 F	2,180	5.0	11.0					
.348 Win.	150 F	2,880	3.0	7.2					
.348 Win.	200 F	2,520	4.0	8.5					
.348 Win. Super Speed	250 F	2,320	4.2	9.2					
.35 Rem	200 R	2,180	5.0	11.0					
.35 Win.	250 R	2,160	5.0	10.7					
.375 H & H Magnum	270 R	2,720	3.0	6.0	10.0				
.375 H & H Magnum	300 R	2,540	3.5	7.5	11.0				
.38-55 W.M. & Sav.	255 F	1,320	13.5						
.405 Win.	300 R	2,220	4.5	10.5					
.45-70 U.S. G	405 R	1,310	14.0						
.45-70 U.S. G	500 R	1,315	13.0	27.0	43.0	60.0	77.0	115.0	167.0
.45-90 Win.	300 F	1,530	11.0						
.45-125 Win. Express	300 F	1,633	9.0						

S—Sharp point (Spitzer)
R—Round nose
H—Hollow Point
F—Flat point
P—Pointed

ANGLES OF ELEVATION

In Minutes
.22 Long Rifle Cartridge
Rifle zeroed at 50 or 75 feet
(There is little or no difference between these two elevations)

Range, yards	*.22 L.R. Regular M.V. 1100 f.s.*	*.22 L.R. High Speed M.V. 1400 f.s.*
	minutes	*minutes*
50	3.7	2.4
75	7.5	5.2
100	11.7	8.2
125	15.8	11.4
150	20.4	14.9
175	24.9	18.3
200	29.6	22.3

Appendix

6

BALLISTIC TABLES

.45-70 Springfield Rifle and Carbine Model 1873 and Subsequent Models

Rifle: 32.6 inch barrel. Cartridge: 70 grains F.G. black powder, 500 grain lubricated lead bullet. M.V. 1315.7 f.s.

Carbine: 22 inch barrel. Cartridge: 70 grains F.G. black powder, 405 grain lubricated lead bullet. M.V. 1150 f.s.

Ordinates of Trajectory above Line of Sight—Rifle

Horizontal Distance	*100 Yards*	*200 Yards*	*300 Yards*	*400 Yards*	*500 Yards*	*600 Yards*	*700 Yards*	*800 Yards*	*900 Yards*	*1,000 Yards*
	feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
100 yards	0									
200 "	1.1	0								
300 "	2.3	2.4	0							
400 "	3.7	5.1	4.1	0						
500 "	5.1	7.9	8.4	5.7	0					
600 "	6.6	10.9	13.0	11.9	7.6	0				
700 "	8.1	14.1	17.6	18.3	15.4	9.4	0			
800 "	9.8	17.4	22.6	24.7	23.9	19.6	11.9	0		
900 "	11.6	21.0	28.2	32.3	33.5	31.2	25.5	15.5	0	
1,000 "	13.5	24.8	34.0	40.3	43.4	43.4	39.8	32.1	18.5	0

Ordinates of Trajectory above Line of Aim—Carbine

Horizontal Distance	*100 Yards*	*200 Yards*	*300 Yards*	*400 Yards*	*500 Yards*	*600 Yards*	*700 Yards*	*800 Yards*	*900 Yards*	*1,000 Yards*
	feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
100 yards	0									
200 "	1.5	0								
300 "	3.2	3.3	0							
400 "	5.2	7.4	5.8	0						
500 "	7.3	11.6	12.3	8.7	0					
600 "	9.7	16.2	19.3	17.9	11.3	0				
700 "	12.1	21.0	26.4	27.3	23.5	14.5	0			
800 "	14.4	25.9	34.0	37.5	36.3	29.7	17.9	0		
900 "	17.3	31.5	42.1	48.3	49.8	45.9	36.8	21.7	0	
1,000 "	20.0	37.1	50.5	59.7	63.8	62.7	56.3	43.9	25.4	0

Elevation, Remaining Velocity, Time of Flight, Energy, Penetration
Rifle

Horizontal Distance	*Angles of Elevation* ° ′ ″	*Remaining Velocity* *f.s.*	*Time of Flight* *seconds*	*Remaining Energy* *ft. lbs.*	*Penetration in White Pine* *inches*
100 yards	17 53	1172	0.25	1525.4	19.1
200 "	31 18	1059.2	0.50	1245.9	16.5
300 "	44 58	986	0.75	1079.6	14.1
400 "	1 0 32	932	1.	964.6	—
500 "	1 17 18	886	1.25	871.7	10.6
600 "	1 34 30	844.5	1.6	792.	—
700 "	1 52 36	806.9	1.97	723.	4.0
800 "	2 12 02	772.4	2.37	662.5	—
900 "	2 34 36	740.7	2.81	609.3	—
1,000 "	2 58 10	711.6	3.29	562.3	—

Elevation, Remaining Velocity, Time of Flight, Energy, Penetration
Carbine

Horizontal Distance	*Angles of Elevation* ° ′ ″	*Remaining Velocity* *f.s.*	*Time of Flight* *seconds*	*Remaining Energy* *ft. lbs.*	*Penetration in White Pine* *inches*
100 yards	22 32	1,018	0.28	930	14.5
200 "	31 23	913	0.58	749	11.4
300 "	43 15	827	0.91	616	9.3
400 "	58 30	757	1.26	515	—
500 "	1 18 36	697	1.62	437	7.25
600 "	1 40 12	646	2.00	376	—
700 "	2 03 23	602	2.40	326	6.3
800 "	2 27 22	564	2.80	286	—
900 "	2 52 52	530	3.21	253	—
1,000 "	3 19 53	500	3.64	225	—

Pressure

Pressure per square inch on the chamber of the gun, about 25,000 pounds.

Drift

It has been found that in firing the rifle with right-hand twist rifling, as in the service rifle, the projectile has a tendency to drift to the right of the plane of

fire. This is reversed in firing with an arm with left-hand twist rifling. This deviation is called the drift.

The drift given in the following table was determined by making alternate targets with right and left hand twist rifles, and taking half of the sum of the distances of the center of impact when on the opposite sides, and half the difference when on the same side of the vertical through the point aimed at, thus eliminating the effect of wind:

Drift to Right for Rifle and Carbine

Range	*Drift*		Range	*Drift*	
	Rifle	*Carbine*		*Rifle*	*Carbine*
	Inches	*Inches*		*Inches*	*Inches*
100 yards	1.29	1.14	600 yards	16.1	15.75
200 "	3	1.33	700 "	21.9	25.44
300 "	5.1	2.8	800 "	28.35	37.30
400 "	7.8	5.0	900 "	35.7	——
500 "	11.5	9.55	1,000 "	42.2	——

Accuracy

Mean results of target practice at the National Armory, the arm being fired from the shoulder with a muzzle rest. Average of a large number of targets, and which may reasonably be expected to be duplicated by a good marksman.

The radius of the circle of shots is the average distance of the shots from the center of impact. The center of impact is the center of the cluster of shots which are aimed at a given point, generally the center of the target. The best recorded targets at 500 yards are, for the rifle, 2.8 inches; carbine, 3.4 inches; at 800 yards for the rifle, 8.5 inches; at 1,000 yards for the rifle, 11.9 inches. (This is mean radius. T.W.):

Radius of Circle of Shots

Range	*Rifle*	*Carbine*	Range	*Rifle*	*Carbine*
	Inches	*Inches*		*Inches*	*Inches*
100 yards	1.3	1.7	600 yards	9.5	15.5
200 "	2.7	4.2	700 "	11.6	19.0
300 "	4.2	6.5	800 "	13.8	23.50
400 "	5.8	9.0	900 "	17.0	26.00
500 "	7.6	11.7	1,000 "	21.4	——

Appendix 7

BALLISTIC TABLES

U.S. Magazine Rifle, Caliber .30, Model 1898, and Carbine Model 1899 (.30-40 Krag-Jorgensen)

Rifle: 30-inch barrel, 220 grain bullet, M.V. 2000 f.s.
Carbine: 22-inch barrel, 220 grain bullet, M.V. 1920 f.s.

Ordinates of Trajectory above Line of Sight
Rifle
(Computed)

Horizontal Distance	*100 Yards*	*200 Yards*	*300 Yards*	*400 Yards*	*500 Yards*	*600 Yards*	*700 Yards*	*800 Yards*	*900 Yards*	*1,000 Yards*
	inches	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
100 yards	0									
200 "	0.46	0								
300 "	0.99	1.07	0							
400 "	1.62	2.32	1.88	0						
500 "	2.36	3.82	4.12	2.98	0					
600 "	3.23	5.54	6.70	6.43	4.31	0				
700 "	4.22	7.53	9.69	10.42	9.30	5.99	0			
800 "	5.35	9.79	13.07	14.92	14.92	12.74	7.88	0		
900 "	6.60	12.29	16.83	19.94	21.19	20.26	16.65	10.03	0	
1,000 "	7.99	15.06	20.99	25.48	28.12	28.57	26.34	21.10	12.46	0

Ordinates of Trajectory above Line of Sight
Carbine
(Computed)

Horizontal Distance	*100 Yards*	*200 Yards*	*300 Yards*	*400 Yards*	*500 Yards*	*600 Yards*	*700 Yards*	*800 Yards*	*900 Yards*	*1,000 Yards*
	inches	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
100 yards	0									
200 "	0.50	0								
300 "	1.08	1.16	0							
400 "	1.76	2.53	2.05	0						
500 "	2.56	4.13	4.46	3.21	0					
600 "	3.50	6.00	7.25	6.94	4.66	0				
700 "	4.56	8.13	10.45	11.20	9.98	6.39	0			
800 "	5.75	10.51	14.02	15.97	15.94	13.54	8.34	0		
900 "	7.08	13.16	18.00	21.27	22.57	21.49	17.62	10.00	0	
1,000 "	8.53	16.06	22.35	27.07	29.82	30.19	27.76	22.19	13.03	0

Angles of Elevation

Range	Rifle		Carbine
	Computed angle of departure	*Angle of elevation found by firing with service sight*	*Computed angle of departure*
Yards	° ′ ″	° ′ ″	° ′ ″
100	0 04 29		0 04 52
200	0 09 43		0 10 33
300	0 15 51	0 09 0	0 17 13
400	0 23 02	0 16 0	0 25 02
500	0 31 35	0 24 0	0 34 14
600	0 41 27	0 34 0	0 44 55
700	0 52 53	0 45 0	0 57 07
800	1 05 47	0 57 0	1 10 47
900	1 20 09	1 11 0	1 25 58
1,000	1 36 01	1 26 0	1 42 34

Remaining Velocity, Remaining Energy, Time of Flight (Computed)

Range	Remaining Velocity		Remaining Energy		Time of Flight	
	Rifle	*Carbine*	*Rifle*	*Carbine*	*Rifle*	*Carbine*
Yards	*f.s.*	*f.s.*	*ft. lbs.*	*ft. lbs.*	*seconds*	*seconds*
100	1,783	1,712	1553.4	1432.1	.159	.165
200	1,590	1,527	1235.3	1139.5	.337	.351
300	1,418	1,361	985.2	905.4	.537	.560
400	1,265	1,217	781.9	723.5	.761	.793
500	1,138	1,100	632.8	591.5	1.012	1.053
600	1,044	1,018	532.6	506.6	1.288	1.337
700	978	958	467.4	448.4	1.585	1.641
800	923	905	416.3	400.4	1.901	1.963
900	874	859	373.3	360.1	2.235	2.303
1,000	831	816	337.4	325.6	2.587	2.662

Penetration in White Pine

	52 feet from muzzle	*500 Yards*	*1,000 Yards*
	Inches	*Inches*	*Inches*
Rifle	45.8	19.85	11.44
Carbine	—	17.96	11.02

Drift

The drift proper of the rifle, it having a right hand twist, should be to the right, but deductions from experimental firing in connection with two standard signal service anemometers and two wind vanes with graduated dials indicate that the bullet deviates to the left of the line of sight up to about 1,100 yards, when it crosses to the right of this line. One anemometer and one wind vane were placed at one-third, and the others at two-thirds the range, and just off the line of fire. With the carbine the drift is always to the right.

Drift of Rifle

100	yards	2.5	inches	left.	900	yards	5.8	inches	left.
200	"	4.3	"	"	1,000	"	3.4	"	"
300	"	5.9	"	"	1,100	"	0.3	"	"
400	"	7.2	"	"	1,200	"	3.5	"	right
500	"	8.1	"	"	1,300	"	7.9	"	"
600	"	8.5	"	"	1,400	"	12.9	"	"
700	"	8.3	"	"	1,500	"	18.5	"	"

Wind

Deviation caused by a one-mile wind normal to plane of fire

100	yards	0.6	inches	600	yards	6.6	inches
200	"	1.3	"	700	"	8.7	"
300	"	2.3	"	800	"	11.1	"
400	"	3.5	"	900	"	13.9	"
500	"	4.9	"	1,000	"	17.0	"

Accuracy

Determined by experimental firing. Radius of circle of shots. (Mean Radius)

100	yards	1.2	inches	600	yards	7.7	inches
200	"	2.1	"	700	"	9.3	"
300	"	3.3	"	800	"	11.1	"
400	"	4.7	"	900	"	13.0	"
500	"	6.2	"	1,000	"	14.9	"

Note: As the above table was published in 1901, these accuracy firings were probably conducted with the 220 grain 3-groove lubricated bullet and Peyton powder.

APPENDIX

8

BALLISTIC TABLES

U.S. Rifle, Caliber .30 M1903 (Springfield), and Ball Cartridge, Caliber .30 M1906 (150 grain pointed bullet, M.V. 2700 f.s.)

Note: These tables will also suffice for the U.S. Rifle, Caliber .30 M1 (Garand), and for the Ball Cartridge, Caliber, 30 M2. The latter cartridge has a muzzle velocity of 2800 f.s., but the increased effect on the flight of the bullet is small.

Table of Fire

[Based on firings made at the Aberdeen Proving Ground in 1922, reduced to tabular conditions [1] and to MV = 2700 f.s.]

Range	*Angle of departure*	*Time of flight*	*Angle of fall*	*Remaining velocity*	*Summit of trajectory.*		*Remaining energy*
					Height	*Distance from muzzle*	
Yards	*Deg. Min.*	*Seconds*	*Deg. Min.*	*Ft. per sec.*	*Feet*	*Yards*	*Ft.-lbs.*
0	0 0	0.0	0 0	2,700	0.00	0	2,429
100	0 2	0.1	0 3	2,481	0.06	53	2,051
200	0 5	0.2	0 6	2,267	0.27	107	1,712
300	0 8	0.4	0 10	2,059	0.62	161	1,412
400	0 12	0.5	0 15	1,858	1.1	215	1,150
500	0 16	0.7	0 22	1,664	2.0	270	923
600	0 20	0.9	0 31	1,481	3.3	328	731
700	0 26	1.1	0 42	1,315	5.0	391	576
800	0 33	1.3	0 57	1,174	7.4	456	459
900	0 40	1.6	1 16	1,065	10.8	523	378
1,000	0 49	1.9	1 38	989	15.3	591	326

H-1-0. 30-2. A.P.G. December, 1922.

[1] Air density at battery, 59° F. and 29.53 inches of mercury.

Maximum range (approximate).

(Actual firing.)

Maximum range	*Elevation*	*Time of flight*
3,450 yards.	30 degrees.	26 seconds.

Horizontal deviation.—The rifle has a right-hand twist, and the drift proper is therefore to the right. There is, however, a slight lateral jump to the left, and the total horizontal deviation of the bullet, excluding wind, is the algebraic sum of the drift and the lateral jump. On account of this slight lateral jump, the trajectory is found to be very slightly to the left of the central or uncorrected line of sight up to a range of 500 yards, and beyond that range to the right of this line. In order to minimize the deviations at the most important ranges, the drift slot on the sight leaf is so cut as to make the trajectory cross the adjusted line of sight at a range of 500 yards. The deviations under these conditions are shown in column (4) of the table below. This drift and the deviations due to wind, given below, have been determined by experimental firings:

Range (*1*)	*Drift with targeted rifles, model of 1905 sights graduated for 1906 ammunition*				
	Total drift (2)		*Drift corrected by sight leaf* (3)		*Drift uncorrected (right)* (4)
	Left	*Right*	*Left*	*Right*	
Yards	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
100	0.26	—	0.26	—	0.0
200	0.42	—	0.42	—	0.0
300	0.45	—	0.45	—	0.0
400	0.32	—	0.32	—	0.0
500	0.0	—	0.0	—	0.0
600	—	0.55	—	0.55	0.0
700	—	2.0	—	1.4	0.6
800	—	4.5	—	2.6	1.9
900	—	8.2	—	4.2	4.0
1,000	—	13.0	—	6.3	6.7

9

RIFLE BALLISTICS OF WINCHESTER CARTRIDGES

1907

Length of Barrel	Cartridge	Weight of Bullet	Velocity at 50 Feet	Energy at 50 Feet	Penetration at 15 Feet ⅞ Inch Pine Boards			Trajectory			Free Recoil in Foot Pounds	
					Lead	S.P.	F.P.	100 Yds. Height at 50 Yds.	200 Yds. Height at 100 Yds.	300 Yds. Height at 150 Yds.	Smoke-less	Black
inches		grains	f.s.	ft. lbs.	boards	boards	boards	inches	inches	inches		
24	.22 Winchester R.F.	45	1,137	121	7			4.25				.32
20	.22 Automatic	45	882	78	5			6.10			.12	
26	.22 Winchester Single Shot	45	1,481	218	8			2.71	12.63	33.67	.39	.51
28	6 mm U.S. Navy	112	2,500	1,553		12	60	.76	3.49	9.14	7.10	
24	.25-20 W.C.F.	86	1,300	323	9	8	11	3.30	13.78	34.69	.80	.88
24	.25-20 W.H.V.	86	1,650	520		10	20	1.85	9.37	26.22	1.36	
28	.25-20 Single Shot	86	1,304	325	9	8	11	3.35	13.61	34.68	.52	.67
26	.25-35 W.C.F.	117	1,925	985		11	36	1.32	6.21	16.61	3.39	
26	.30 W.C.F.	170	1,960	1,449		11	42	1.28	5.79	15.23	7.20	
26	.303 Savage	190	1,925	1,564		11	42	1.30	5.85	16.28	8.31	
28	.303 British	215	1,960	1,833		13	56	1.23	5.52	14.08	10.98	
28	.30 U.S. Army	220	1,960	1,880		13	58	1.22	5.47	13.55	11.59	
24	.30 U.S.G.M. .03 Rimless	220	2,163	2,286		18	68	1.00	4.52	11.40	16.13	
24	.32 Winchester	115	1,177	352	6.5	6.5	10	3.46	15.37	37.21	1.11	1.24
24	.32-20 W.H.V.	115	1,575	633		7	17	2.10	10.70	29.89	2.66	

26	.32-40	165	1,385	702	8.5	8.5	18	2.56	12.21	31.90	3.08	4.13
26	.32-40 W.H.V.	165	1,700	1,058		10.	30	1.70	8.23	22.08	5.45	
26	.32 W.S. Smokeless	170	2,050	1,585		12	45	1.17	5.60	15.26	7.66	
26	.32 W.S. Black	170	1,385	724	9			2.56	12.21	31.90		4.41
22	.32 Self-Loading	165	1,350	668		10	17	2.70	1,248	33.25		
24	.33 W.C.F.	200	2,000	1,775		13	39	1.21	5.78	15.51	11.25	
24	.35 W.C.F.	250	2,150	2,567		15	56	1.03	4.73	12.24	19.81	
22	.35 Self-Loading	180	1,350	729		9	17	2.74	13.07	34.34		
20	.351 Self-Loading	180	1,800	1,295		13	26	1.55	7.60	21.10		
24	.38 Winchester	180	1,268	644	7.5	10	12	3.19	14.42	35.68	3.20	4.69
24	.38-40 W.H.V.	180	1,700	1,154		10	20	1.80	9.46	27.33	6.67	
26	.38-55	255	1,285	934	9.5	13.5	17	2.97	12.92	31.98	5.96	8.41
26	.38-55 W.H.V.	255	1,550	1,360		10	23	2.01	9.52	25.46	9.42	
26	.38-56 Winchester	255	1,359	1,047	11	12	17	2.82	12.23	30.14	5.76	8.13
26	.38-70 Winchester	255	1,449	1,190	10	12	19	2.58	10.58	27.17	7.16	10.24
26	.38-72 Winchester	275	1,443	1,293	16	15	25	2.24	10.58	27.67	8.70	9.40
30	.38-90 Winchester Express	217	1,546	1,149	9			2.05	10.15	27.49		9.58
28	.40-60 Marlin	260	1,419	1,163	8.5			2.97	11.81	29.40		7.69
28	.40-60 Winchester	210	1,475	1,014	9.5			2.61	11.65	30.11		6.94
26	.40-65 Winchester	260	1,325	1,013	9	11	14.5	2.85	12.00	30.67	6.80	8.68
26	.40-70 Winchester	330	1,349	1,335	13	11	19.5	2.89	11.79	29.44	9.23	12.95
26	.40-70 Sharps Straight	330	1,229	1,108	11.5			3.30	13.40	32.86		11.33
26	.40-72 Winchester, Black	330	1,359	1,386	13			2.59	12.21	30.50		14.56
26	.40-72 Winchester, Smokeless	300	1,386	1,307		14	22	2.43	11.63	28.54	9.99	
26	.40-82 Winchester	260	1,445	1,205	12	11	17.5	2.56	11.92	30.32	8.79	12.19
30	.40-90 Sharps Straight	370	1,357	1,508	16			2.73	10.76	26.85		15.35
30	.40-110 Winchester Express	260	1,555	1,395	12			2.07	8.95	23.63		16.73
24	.405 W.C.F.	300	2,150	3,077		13	48	1.05	4.68	12.82	28.24	
24	.44 Winchester	200	1,245	688	9	10	13	3.36	15.27	37.39	3.93	5.42
24	.44-40 W.H.V.	200	1,500	999		10	14	2.32	12.12	33.64	5.98	

Length of Barrel	Cartridge	Weight of Bullet	Velocity at 50 Feet	Energy at 50 Feet	Penetration at 15 Feet 7/8 Inch Pine Boards			Trajectory			Free Recoil in Foot Pounds	
					Lead	S.P.	S.P.	100 Yds. Height at 50 Yds.	200 Yds. Height at 100 Yds.	300 Yds. Height at 150 Yds.	Smoke-less	Black
inches		grains	f.s.	ft. lbs.	boards	boards	boards	inches	inches	inches		
30	.45-60 Winchester	300	1,271	1,075	11.5			3.16	13.67	33.10		9.28
26	.45-70-350 Winchester	350	1,307	1,327	13	11	17	2.79	13.13	32.35	10.28	14.57
26	.45-70-330 Gould Hollow	330	1,338	1,315	10			2.82	12.66	31.76		12.70
26	.45-70-405 U.S.G.	405	1,286	1,652	13	12	18	4.12	12.33	29.00	12.27	16.24
26	.45-70 W.H.V.	300	1,825	2,214		13	15	1.47	7.40	19.65	16.16	
26	.45-70-500 U.S.G.	500	1,179	1,542	18	15	20	3.66	14.36	34.36	15.22	18.43
30	.45-75 Winchester	350	1,343	1,401	14.5			3.04	12.41	30.62		13.61
26	.45-90 Winchester	300	1,480	1,457	13	15	19	2.44	10.25	27.25	11.38	16.53
26	.45-90 W.H.V.	300	1,925	2,466		14	26	1.41	6.63	17.73	18.99	
30	.45-125 Winchester Express	300	1,633	1,775	9.5			2.19	9.01	25.11		22.93
30	.50-95 Winchester Express	300	1,493	1,484	10			2.58	12.57	33.51		17.48
26	.50-110 Winchester Express	300	1,536	1,571	11	12.5	20	2.53	11.91	33.52	11.32	19.76
26	.50-110 W.H.V.	300	2,150	3,077		14	26	1.07	5.82	17.28	25.62	
26	.50-100-450 Winchester	450	1,383	1,719	16	14	20	2.85	11.94	30.69	21.53	25.17

Note: Compare the large caliber, black powder, express cartridges with the better balanced loads of similar caliber. For example, the .38-90 with the .38-72; the .40-110 with the .40-72; the .45-70-330 Gould with the .45-70-405; and the .45-125 with the .45-90. The trajectory of the express loads was only microscopically flatter, the penetration was not so good, the recoil was greater; and (not shown) the cartridge was more expensive and the accuracy not nearly so good. It is difficult to account for the logic that caused the introduction of these express cartridges.—T. W.

Appendix

10

WINCHESTER BALLISTICS, 1941

Rim Fire Rifle Cartridges

Cartridge	Bullet		Velocity		Energy		Trajectory for 100 Yds. Hgt. at 50 Yds. Inches
	Type	Wt. Grs.	Muzzle	100 Yds.	Muzzle	100 Yds.	
B.B. Caps	Lead Gr.	18	780	570	24	13	
C.B. Caps	Lead Gr.	29	720	605	33	24	
.22 Short Spotlight	Lead Gr.	26	970				
Leader .22 Short Staynless	Lead Gr.	29	1,030	860	68	48	5.1
Spatterproof .22 Short	Lead Gr.	26	970				
Super Speed .22 Short, Kopperklad, Wax coated	K.K.	29	1,130	925	82	55	4.1
Super Speed .22 Short, Kopperklad, Hollow Point, Wax Coated	K.K., H.P.	27	1,155	925	80	51	4.1
Leader .22 Long, Staynless	Lead Gr.	29	1,080	900	75	52	4.3
Super Speed .22 Long, Kopperklad, Wax Coated	K.K.	29	1,375	1,020	122	67	3.2
Super Speed .22 Long, Kopperklad, Hollow Point, Wax coated	K.K., H.P.	27	1,395	1,010	117	61	3.3
Leader .22 Long Rifle, Staynless	Lead Gr.	40	1,180	995	124	88	3.8
Precision EZXS .22 Long Rifle, Lesmok	Lead Gr.	40	1,100	950	108	80	4.3
Super Speed .22 Long Rifle, Kopperklad, Wax Coated	KK	40	1,375	1,080	168	104	2.9
Super Speed .22 Long Rifle, Kopperklad, Hollow Point, Wax Coated	K.K., H.P.	37	1,400	1,075	161	95	3.0
.22 Extra Long	Lead	40	1,030	900	94	72	4.9
.22 W.R.F. Staynless (inside lubricated)	Lead Gr.	45	1,105	955	122	91	4.0
Super Speed .22 W.R.F., Kopperklad (inside lubricated)	K.K.	45	1,450	1,110	210	123	2.7
Super Speed .22 W.R.F., K.K., H.P. (inside lubricated)	K.K., H.P.	40	1,475	1,095	193	107	2.7
.22 Auto (inside lubricated)	Lead	45	1,055	930	111	86	4.6
.25 Stevens, Staynless	Lead Gr.	65	1,130	985	184	140	3.8
.41 Swiss, Staynless	Lead Gr.	310	1,325	1,165	1,210	935	2.9

Rim Fire Revolver Cartridges *

Cartridge	Bullet Weight	Muzzle Velocity	Muzzle Energy.	Cartridge	Bullet Weight	Muzzle Velocity	Muzzle Energy.
Super Speed .22 Short	29	1035	69	Leader .22 Long Rifle	40	980	85
Leader .22 Short	29	925	55	Super Speed .22 W.R.F.	45	1170	137
Super Speed .22 Long	29	1125	81	.22 W.R.F. Staynless	45	985	97
Leader .22 Long	29	930	56	.41 Short Staynless	130	520	78
Super Speed .22 Long Rifle	40	1160	120				

* Fired in revolvers with 6 inch barrels.

Center Fire Rifle Cartridges

Primer No.	Cartridge	Bullet		Velocity		Energy		Trajectory in Inches		
		Type	*Grs. Wt.*	*Muzzle*	*100 Yds.*	*Muzzle*	*100 Yds.*	*100 Yds. Hgt. at 50 Yds.*	*200 Yds. Hgt. at 100 Yds.*	*300 Yds. Hgt. at 150 Yds.*
116	Super Speed .218 Bee	H.P.	46	2,860	2,260	835	520	0.7	3.5	10.5
116	Super Speed .218 Bee	S.P.	45	2,860	2,250	820	505	0.7	3.5	10.5
115	Super Speed .219 Zipper	H.P.	46	3,390	2,720	1,175	755	0.4	2.5	7.0
115	Super Speed .219 Zipper	H.P.	56	3,050	2,530	1,155	793	0.6	2.5	8.0
116	Super Speed .22 Hornet	S.P.	45	2,650	2,780	700	430	0.8	4.0	12.5
116	Super Speed .22 Hornet	H.P.	46	2,650	2,090	715	445	0.8	4.0	12.5
115	Super Speed .22 Savage High Power	P.S.P.	70	2,780	2,480	1,200	955	0.6	3.0	7.0
120	Super Speed .220 Swift	P.S.P.	55	3,720	3,250	1,690	1,290	0.35	1.5	4.5
120	Super Speed .220 Swift	P.S.P.	48	4,140	3,490	1,825	1,300	0.3	1.5	3.5
116	.25-20 W.C.F. (Also F.P. and S.P.)	Lead	86	1450	1190	400	270	2.6	11.5	31.5
116	Super Speed .25-20 W.H.V.	S.P.	86	1,710	1,380	560	365	1.8	9.0	25.0
116	Super Speed .25-20 Winchester	H.P.	60	2,210	1,700	650	385	1.1	6.0	18.5
116	.25-20 Single Shot	S.P.	86	1,380	1,150	365	255	2.6	13.0	33.5
115	.25 Remington Auto.	S.P.	117	2,300	2,020	1,375	1,060	0.9	4.5	11.0
120	6.5 mm Mannlicher	S.P.	145	2,360	2,110	1,795	1,435	0.9	4.0	10.0
115	Super Speed .25-35 Winchester	S.P.	117	2,280	1,970	1,350	1,010	1.0	4.5	12.0
120	Super Speed .257 Roberts	P.S.P.	87	3,180	2,870	1,955	1,590	0.5	2.0	5.5
120	Super Speed .257 Roberts	P.E.	100	2,860	2,610	1,815	1,515	0.6	2.5	6.5
115	Super Speed .250-3,000 Savage	P.S.P.	87	3,000	2,710	1,740	1,420	0.5	2.5	6.0
115	Super Speed .250-3,000 Savage	P.E.	100	2,790	2,550	1,730	1,445	0.6	2.5	6.5

120	Super Speed .270 Winchester	P.E.	130	3,120	2,880	2,810	2,395	0.5	2.0	5.0
120	Super Speed .270 Winchester	S.P.	150	2,770	2,490	2,560	2,065	0.6	3.0	7.0
120	Super Speed .270 Winchester	P.E.	100	3,540	3,210	2,785	2,290	0.4	1.5	4.5
120	Super Speed 7 mm Mauser	S.P.	175	2,460	2,220	2,350	1,915	0.8	3.5	9.0
120	Super Speed 7 mm Mauser	P.E.	150	2,750	2,550	2,520	2,165	0.6	2.5	6.5
120	7.62 m/m Russian	H.C.P.	143	2,810	2,570	2,545	2,130	0.6	2.5	6.5
115	Super Speed .30-30 Winchester	S.P.	170	2,200	1,930	1,830	1,405	1.0	4.5	12.0
115	Super Speed .30-30 Winchester	H.P.	110	2,720	2,260	1,810	1,250	0.7	3.5	10.0
115	Super Speed .30-30 Winchester	H.P.	150	2,380	2,060	1,890	1,415	0.9	4.0	11.0
115	.30 Remington Auto	S.P.	170	2,200	1,930	1,830	1,405	1.0	4.5	12.0
115	Super Speed .300 Savage	S.P.	150	2,660	2,430	2,360	1,970	0.7	3.0	7.5
115	Super Speed .300 Savage	S.P.	180	2,380	2,140	2,265	1,830	0.8	4.0	10.0
115	.303 Savage	S.P.	190	1,960	1,740	1,620	1,280	1.3	6.0	14.5
115	Super Speed .303 British	S.P.	215	2,160	1,940	2,230	1,795	1.0	4.5	11.5
115	.30 Army (.30-40 Krag) Also F.P.	S.P.	220	2,190	1,980	2,345	1,915	1.0	4.5	11.0
115	Super Speed .30 Army (.30-40 Krag)	P.E.	150	2,660	2,430	2,360	1,970	0.7	3.0	7.5
115	Super Speed .30 Army (.30-40 Krag)	P.E.	180	2,460	2,250	2,420	2,020	0.7	3.5	8.0
115	Super Speed .30 Army (.30-40 Krag)	S.P.	180	2,480	2,210	2,460	1,955	0.8	3.5	9.0
120	Super Speed .30-06 U.S.	P.E.	150	2,960	2,720	2,920	2,465	0.5	2.5	6.0
120	.30-06 U.S. Pointed Also P.E.	F.P.	180	2,690	2,500	2,895	2,500	0.6	3.0	7.0
120	Super Speed .30-06 U.S.	S.P.	180	2,710	2,420	2,940	2,340	0.7	3.0	7.5
120	.30-06 U.S.	S.P.	220	2,410	2,190	2,840	2,345	0.8	3.5	9.0
120	.30-06 U.S. B.T. Precision	F.P.	172	2,700	2,500	2,785	2,385	0.6	3.0	6.5
120	.30-06 U.S. Wimbledon Cup. B.T.	F.P.	180	2,690	2,500	2,895	2,500	0.6	3.0	7.0
120	.300 H. & H. Magnum Match B.T.	F.P.	180	3,030	2,820	3,670	3,180	0.5	2.0	5.5

Primer No.	Cartridge	Bullet		Velocity		Energy		Trajectory in Inches		
		Type	Grs. Wt.	Muzzle	100 Yds.	Muzzle	100 Yds.	100 Yds. Hgt. at 50 Yds.	200 Yds. Hgt. at 100 Yds.	300 Yds. Hgt. at 150 Yds.
120	Super Speed .300 H. & H. Magnum B.T.	P.E.	150	3,090	2,840	3,180	2,690	0.5	2.0	5.5
120	Super Speed .300 H. & H. Magnum B.T.	P.E.	180	2,900	2,700	3,365	2,920	0.5	2.5	6.0
120	Super Speed .300 H. & H. Magnum B.T.	S.P.	220	2,610	2,380	3,330	2,770	0.7	3.0	7.5
120	8 mm (7.9 mm) Mauser	S.P.	236	2,100	1,890	2,310	1,875	1.1	5.0	12.0
120	Super Speed 8 mm Mauser B.T.	S.P.	170	2,530	2,210	2,415	1,845	0.8	3.5	9.0
112	.32-20 Winchester	Lead	100	1,280	1,060	365	250	3.1	15.0	40.5
112	.32-20 Winchester	S.P.	115	1,280	1,080	420	300	3.1	14.5	37.5
116	Super Speed .32-20 W.H.V.	S.P.	115	1,600	1,290	655	425	2.2	10.0	27.5
116	Super Speed .32-20 Winchester	H.P.	80	2,050	1,520	745	410	1.4	7.5	23.0
115	Super Speed .32 Winchester Special	S.P.	170	2,260	1,960	1,930	1,450	1.0	4.5	12.0
115	Super Speed .32 Winchester Special	H.P.	110	2,630	2,140	1,690	1,120	0.7	3.5	11.5
116	.32 Winchester Self Loading	S.P.	165	1,390	1,190	710	520	2.6	12.5	31.0
115	.32 Remington Auto	S.P.	165	2,200	1,900	1,775	1,325	1.0	4.5	12.5
115	.32-40 W.M. & S.	S.P.	165	1,440	1,230	760	555	2.6	12.0	28.0
120	.33 Winchester	S.P.	200	2,180	1,870	2,110	1,555	1.1	5.0	13.5
120	Super Speed .348 Winchester	S.P.	150	2,880	2,380	2,765	1,890	0.6	3.0	8.5
120	Super Speed .348 Winchester	S.P.	200	2,520	2,160	2,820	2,075	0.8	4.0	10.0
120	.35 Winchester	S.P.	250	2,160	1,910	2,590	2,025	1.1	5.0	12.0
116	.35 Winchester Self Loading	S.P.	180	1,390	1,170	775	545	2.5	13.0	31.0
115	.35 Remington Auto.	S.P.	200	2,180	1,870	2,110	1,555	1.0	5.0	15.0

116	.351 Winchester Self Loading	S.P.	180	1,850	1,560	1,370	975	1.5	7.5	19.0
120	Super Speed .375 H. & H. Magnum	S.P.	270	2,720	2,460	4,440	3,630	0.7	3.0	7.0
120	Super Speed .375 H. & H. Magnum	S.P.	300	2,540	2,290	4,300	3,495	0.7	3.5	8.5
120	Super Speed .375 H. & H. Magnum	F.P.	300	2,580	2,300	4,435	3,525	0.7	3.5	8.5
111	.38-40 W.C.F.	S.P.	180	1,310	1,090	685	475	3.2	15.5	37.5
111	.38-40 W.H.V.	S.P.	180	1,770	1,380	1,255	760	1.7	9.0	24.5
115	.38-55 W.M. & S.	S.P.	255	1,320	1,150	985	750	3.0	13.5	32.5
120	.38-56 Winchester	S.P.	255	1,400	1,210	1,110	830	2.7	11.5	29.0
120	.38-72 Winchester	S.P.	275	1,480	1,300	1,340	1,030	2.4	10.0	26.5
120	.40-65 Winchester	S.P.	260	1,360	1,170	1,070	790	2.9	12.0	30.5
120	.40-82 Winchester	S.P.	260	1,500	1,260	1,300	915	2.3	11.0	27.0
115	.401 Winchester Self Loading	S.P.	200	2,140	1,750	2,035	1,360	1.1	5.5	16.5
120	.405 Winchester	S.P.	300	2,220	1,940	3,285	2,510	1.0	4.5	12.0
111	.44-40 W.C.F.	S.P.	200	1,300	1,070	750	510	3.3	17.5	38.0
111	.44-40 W.H.V.	S.P.	200	1,570	1,220	1,095	660	2.2	11.0	30.0
120	.45-10-405 U.S. Govt.	S.P.	405	1,340	1,160	1,545	1,210	2.8	14.0	32.5
120	.45-90 Winchester	S.P.	300	1,530	1,270	1,560	1,075	2.2	11.0	26.5

S.P.—Soft Point H.P.—Hollow Point F.P.—Full Patch P.E.—Pointed Expanding H.C.P.—Hollow Copper Point B.T.—Boat Tail P.S.P.—Pointed Soft Point W.C.F.—Winchester Center Fire W.H.V.—Winchester High Velocity.

Super Speed, Center Fire Rifle Cartridges—Silvertip Bullet

Primer No.	Cartridge	Bullet	Velocity				Energy				Mid Range Trajectory		
		Grains Weight	Muzzle	100 Yds.	200 Yds.	300 Yds.	Muzzle	100 Yds.	200 Yds.	300 Yds.	100 Yds.	200 Yds.	300 Yds.
115	.250-3,000 Savage	100	2,810	2,490	2,180	1,900	1,755	1,375	1,055	800	0.6	3.0	7.0
120	.257 Win. Roberts	100	2,900	2,570	2,260	1,970	1,870	1,465	1,135	860	0.6	2.5	7.0
120	.270 Winchester	130	3,120	2,880	2,660	2,440	2,810	2,395	2,050	1,720	0.5	2.0	5.0
115	.30-30 Winchester	170	2,200	1,930	1,680	1,460	1,830	1,405	1,065	805	1.0	4.5	12.0
115	.30 Remington Auto.	170	2,200	1,930	1,680	1,460	1,830	1,405	1,065	205	1.0	4.5	12.0
120	.30-06 U.S.	180	2,710	2,420	2,150	1,900	2,940	2,340	1,850	1,445	0.7	3.0	7.5
120	.30-06 U.S.	220	2,410	2,190	1,970	1,780	2,840	2,345	1,900	1,550	0.8	3.5	9.0
115	.30 Army (.30-40 Krag)	180	2,480	2,210	1,950	1,710	2,460	1,955	1,520	1,170	0.7	3.5	9.0
115	.30 Army (.30-40 Krag)	220	2,190	1,980	1,780	1,600	2,345	1,915	1,550	1,250	1.0	4.5	11.0
120	.300 H. & H. Magnum	180	2,930	2,630	2,340	2,080	3,435	2,765	2,190	1,730	0.5	2.5	6.5
120	.300 H. & H. Magnum	220	2,610	2,340	2,160	1,950	3,330	2,770	2,280	1,860	0.7	3.0	7.5
115	.300 Savage	180	2,380	2,140	1,910	1,700	2,265	1,830	1,460	1,155	0.8	4.0	10.0
115	.303 Savage	190	1,960	1,740	1,530	1,350	1,620	1,280	990	770	1.3	6.0	14.5
115	.32 Winchester Special	170	2,260	1,960	1,690	1,450	1,930	1,450	1,080	795	1.0	4.5	12.0
115	.32 Remington Auto	170	2,200	1,910	1,640	1,400	1,830	1,380	1,015	740	1.0	5.0	13.0
120	.348 Winchester	250	2,320	2,046	1,793	1,566	2,980	2,330	1,790	1,362	0.9	4.2	10.8
115	.35 Remington Auto.	200	2,180	1,870	1,590	1,360	2,110	1,555	1,125	820	1.0	5.0	13.0
120	.375 H. & H. Magnum	300	2,540	2,290	2,050	1,830	4,300	3,495	2,800	2,250	0.7	3.5	8.5

Appendix

Recoil and Penetration of Winchester Cartridges
1941

Cartridge	*Bullet Weight grains*	*Muzzle Velocity f.s.*	*Weight of Rifle pounds*	*Recoil Ft. Lbs.*	*Penetration at 15 Feet 7/8 in Soft Pine Boards*	
					Soft Point	*Full Patch*
Super Speed .22 Hornet	46	2,625	8.2	0.7		
Super Speed .220 Swift	48	4,140	8.7	4.7	13	
.25-20 W.H.V.	86	1,730	6.5	1.5	10	20
.25-35 W.C.F.	117	2,250	7.	4.5	11	44
.257 Roberts	100	2,900	8.	6.9	10	
.270 Winchester	130	3,160	8	14.3	17	
.30-30 W.C.F.	170	2,200	7	9.0	11	50
.30-40 Krag	220	2,100	8.5	11.5	13	58
.30 M1903 U.S. Govt.	220	2,200	9.	15.0	18	68
.30-06 Pointed Exp.	180	2,700	8.	17.5	17	
.30-06	220	2,400	8.	19.0	17	
.30-06 U.S. G.B.T. (M1)	172	2,700	8.	16.0	17	
.300 H. & H. Magnum FPBT	180	3,060	8.5	25.1		
.300 H. & H. Magnum SP	220	2,730	8.5	27.2		
.303 British	215	2,000	8.5	11.0	13	56
.32-20 W.H.V.	115	1,635	6.5	2.5	7	17
.32 Win. Special	170	2,250	7.	9.5	12	52
.32-40 W.H.V.	165	1,750	7.	5.5	10	30
.33 Winchester	200	2,200	8.	13.5	13	45
.348 Winchester	200	2,535	8.	22.6	17	
.35 Winchester	250	2,195	8.5	20.0	15	56
.351 Win Self-Loading	180	1,855	7.	5.5	13	26
.375 H. & H. Magnum	235	2,870	9.	31.2		
.375 H. & H. Magnum	300	2,563	9.	33.6		
.38-40 W.H.V.	180	1,770	6.5	6.5	10	20
.38-55 W.H.V.	255	1,590	7.	9.5	10	23
.401 Win. Self-Loading	200	2,135	8.	11.5	14	34
.405 Winchester	300	2,200	8.5	28.0	13	48
.44-40 W.H.V.	200	1,565	6.5	6.0	10	19
.45-70 W.H.V.	300	1,885	9	16.0	13	25
.45-70-405 Govt.	405	1,320	9	12.0	12	18

Pistol and Revolver Center Fire Cartridges

Primer No.	Cartridge	Bullet Type	Bullet Wt. Grs.	Muzzle Velocity f.s.	Muzzle Energy Ft. Lbs.	Penetration ⅞" Soft Pine Boards at 15 Ft.	Barrel Length Inches
108	.25 Auto Colt (6.35 m/m)	F.P.	50	820	75	3	2
108	.32 S. & W. Staynless	Lead	85	720	98	3	3
108	.32 S. & W. Long, Staynless	Lead	98	820	146	4	4.25
108	7.63 m/m Mauser (.30 Mauser)	F.P.	86	1,420	385	11	5.5
108	7.65 m/m Luger (.30 Luger)	F.P.	93	1,250	323	11	4.5
108	.32 Short Colt	Lead	80	800	114	3	4.
108	.32 Long Colt	Lead	82	800	117	3	4
108	.32 Automatic Colt (7.65 m/m)	F.P.	74	980	158	5	4
108	.32 S. & W. Long, Sharp Corner Match	Lead	98	770	129	—	6
112	.32-20 Winchester Staynless	Lead	100	1,030	235	6	6
108	.32 Colt New Police	Lead	98	795	138	3	4.
111	Super Speed S. & W. .357 Magnum	Lead	158	1,510	800	12.5	8.75
108	9 m/m Luger	F.P.	125	1,150	367	10.	4.
108	.38 Colt New Police	Lead	150	695	161	4	4
108	.38 Short Colt	Lead	130	770	171	4	6

108	.38 S. & W. Staynless	Lead	145	745	179	4	4
108	.38 S. & W.	Lead	200	630	176	5	4
111	Super Speed .38 Special	Lead	158	1,115	436	7.5	5
111	Super Speed .38 Special, lead bearing	Metal Pt.	158	1,115	436	10.	5
111	Super Speed .38 Special, metal piercing	M.P.	150	1,175	460	11.	5
108	.38 Colt Special	Lead	158	870	266	6.5	6
108	.38 S. & W. Special, Staynless	Lead	158	870	266	7.	6
108	.38 S. & W. Special	Lead	200	745	247	7.5	6
108	.38 S. & W. Special, Mid Range, Sharp Corner	Lead	148	770	195	—	6
108	.38 S. & W. Special, Full Charge, Sharp Corner	Lead	148	870	249	—	6
112	.38 Automatic Colt	F.P.	130	1,070	331	9	4.5
112	Super Speed .38 Automatic Colt	F.P.	130	1,300	488	10	5.
108	.38 Long Colt	Lead	150	785	205	6	6
108	.380 Automatic Colt	F.P.	95	970	199	5.5	3.75
108	.41 Long Colt	Lead	196	745	242	5	6
111	.44 S. & W. Russian	Lead	246	770	324	4	6.5
111	.44 S. & W. Special	Lead	246	770	324	7.5	6.5
111	.45 Colt	Lead	255	870	429	6	5.5
111	.45 Automatic Colt	F.P.	230	860	378	6	5
111	.45 Auto Rim	Lead	230	820	343	6	5.5
111	.45 Auto Rim	F.P.	230	820	343	6	5.5
111	.45 Auto. Colt Match	F.P.	230	750	287	—	5

APPENDIX

11

TABLE OF SHOT SIZES

American Standard Shot

Size	*Chilled Shot No. in Ounce*	*Drop Shot No. in Ounce*	*Diameter in Inches*	*Diameter in Millimeters*
Dust		4,565	.04	1.02
No. 12	2,385	2,326	.05	1.27
11	1,380	1,346	.06	1.52
10	868	848	.07	1.78
9	585	568	.08	2.03
8	409	399	.09	2.28
7½	345	338	.09½	2.41
7	299	291	.10	2.54
6	223	218	.11	2.79
5	172	168	.12	3.02
4	136	132	.13	3.30
3	109	106	.14	3.53
2	88	86	.15	3.78
1	73	71	.16	4.06
B	59		.17	4.32
Air Rifle	55		.17½	4.44
No. BB	50		.18	4.57
BBB	42		.19	4.83
T	36		.20	5.08
TT	31		.21	5.33
F	27		.22	5.59
FF	24		.23	5.84

Buckshot

Eastern Size	*Western Size*	*Diameter Inches*	*Diameter Millimeters*	*Number in Pound*
No. 4		.24	6.09	341
3	8 or 9	.25	6.35	299
2	7	.27	6.86	238
1	5 or 6	.30	7.62	175
0	4	.32	8.13	144
00	3	.34	8.64	122
000	2	.36	9.14	103

Lead Balls

Size	*Diameter Inches*	*Diameter Millimeters*	*Number in Pound*
.44 Game Getter	.425	10.79	60
.44 S. & W. Russian Gallery	.428	10.87	58
.45-5 Armory Practice	.452	11.48	50
½ Inch	.500	12.70	38
28 Gauge	.510	12.95	35

APPENDIX

12

TABLE OF BRITISH SHOT SIZES

Size	*Number of Pellets in Ounce*	*Diameter of Pellet in Inches*
LG	6	.3648
MG	7	.3465
SG	8	.3314
Special S.G	11	.2981
SSG	15	.2701
SSSG	20	.2443
SSSSG	25	.2267
SSSSSG or AAAA	30	.2133
AAA	35	.2026
AA	40	.1937
A	50	.1799
BBB	60	.1693
BB	70	.1608
B	80	.1537
1	100	.1428
2	120	.1344
3	140	.1276
4	170	.1196
4½	200	.1133
5	220	.1098
5½	240	.1067
6	270	.1023
6½	300	.0990
7	340	.0950
8	450	.0865
9	580	.0795
10	850	.0700

13

Recoil in Foot Pounds of 12-Gauge du Pont Smokeless Loads

Load	Muzzle Velocity Ft. Sec.	*Recoil in Foot Pounds with Guns of Different Weights . . .*												
		6-lb. Gun	*6¼-lb. Gun*	*6½-lb. Gun*	*6¾-lb. Gun*	*7-lb. Gun*	*7¼-lb. Gun*	*7½-lb. Gun*	*7¾-lb. Gun*	*8-lb. Gun*	*8¼-lb. Gun*	*8½-lb. Gun*	*8¾-lb. Gun*	*9-lb. Gun*
3-1	1,218	20.5	19.9	19.0	18.2	17.6	17.2	16.5	16.2	15.6	15.2	14.9	14.4	13.7
3¼-1	1,314	24.0	23.0	22.2	21.0	20.4	19.8	19.0	18.9	18.3	17.7	17.2	16.7	16.0
3½-1	1,424	28.0	27.2	26.0	24.8	24.2	23.5	22.5	22.0	21.4	20.8	20.1	19.6	19.0
3-1⅛	1,180	24.0	23.0	22.2	21.0	20.4	19.8	19.0	18.6	18.0	17.2	16.7	16.4	16.0
3¼-1⅛	1,278	27.9	26.8	26.0	24.8	24.2	23.5	22.5	21.6	21.0	20.4	19.7	19.2	19.0
3½-1⅛	1,376	32.3	31.2	29.9	28.9	28.0	26.8	26.0	25.0	24.4	23.6	22.9	22.2	21.9
3-1¼	1,148	27.6	26.2	25.2	24.2	23.5	22.9	21.8	21.0	20.4	19.9	19.6	19.2	18.6
3¼-1¼	1,240	32.3	30.9	29.5	28.6	27.6	26.8	25.6	24.7	24.1	23.4	22.8	22.1	21.5
3½-1¼	1,338	37.4	35.8	34.5	33.3	32.2	31.0	30.0	28.6	28.0	27.0	26.6	25.8	24.8

APPENDIX
14
Ballistics of Low Power Weapons
(from British "Text Book of Small Arms, 1929")

Weapon	*Snider Rifle*	*Martini Henry Rifle*	*.22 Rim Fire Rifle*	*12 Bore Shotgun No. 6 Shot*
W/d^2 M.V. f.s.	0.20 1200	0.339 1315	0.12 1000	0.02 1315
Elevation degrees	Ranges obtained at various elevations. Yards			
½	206	250	155	26
1	360	450	275	47
1½	480	630	370	62
2	593	800	460	74
3	775	1,050	580	92
4	917	1,280	675	108
5	1,040	1,460	750	122
Greatest range @ about 30 degrees	2,500?	3,000?	1,300	167 @ 10° 230 @ 30°
Value C	0.125	0.20	0.10	0.015
Value n	1.6	1.7	1.2	1.3

DU PONT EXTERIOR BALLISTIC CHARTS
(In back pocket)

1 DETERMINING COEFFICIENT OF BULLET FORM
2 DETERMINING BALLISTIC COEFFICIENT (C)
3 DETERMINING REMAINING VELOCITY.
4 DETERMINING ANGLE OF DEPARTURE.
5 DETERMINING TIME OF FLIGHT.
6 DETERMINING MAXIMUM HEIGHT OF TRAJECTORY.
7 DETERMINING ANGLE OF FALL.
8 DETERMINING WIND DEFLECTION.
9 DETERMINING ENERGY OF PROJECTILE.
10 CORRECTIONS APPLYING TO CHARTS.

APPENDIX

15

The British Lee Enfield Rifle and Cartridge

(From British "Text Book of Small Arms, 1929" Official)

Rifle: Short Model, Lee Enfield, Mark III.

Weight without bayonet	8 lbs. 10½ oz.
Magazine capacity	10 rounds.
Barrel length	25.19 inches.
Barrel caliber (bore diam.)	.303 inch.
Twist, one turn in	10 inches.
Twist, one turn in	33 calibers.
Direction of twist	To left.

Cartridge: .303 British, Mark VII.

Overall length, inches	3.0357 (mean)
Weight, grains	384 (mean)
Case	Rim
Bullet shape	Pointed
Bullet base	Flat
Bullet jacket	Cupro-nickel *
Material of core	Lead and antimony
Bullet length	1.28 inches
Bullet diameter	.312 inch
Bullet weight	174 grains (mean)
Powder charge, Cordite *	37.5 grains
Value of w/d^2	0.255
Muzzle velocity, f.s.	2440
Chamber pressure, (Tons per square inch)	19.5

* Later changed to gilding metal jacket and nitro-cellulose powder.

Range Table for above Rifle and Cartridge

Range, yards	*Elevation, minutes*	*Time Flight, seconds*	*Velocity, F.S.*
0	0	0	2440
100	3	0.2	2230
200	7	0.3	2030
300	11	0.4	1840
400	15	0.6	1660
500	19	0.8	1500
600	25	1.0	1360
700	32	1.2	1240
800	40	1.5	1140
900	49	1.8	1060
1000	60	2.1	1000

INDEX

Aberdeen Chronograph, 48
Accuracy, 84, 109, 177
  of bullets, 179
  of first shot, 180
  of old rifles, 238
Advice to Young Sportsmen, 111
Air resistance, 73, 74
Air spiral, 83
Altitude, 114
Angles,
  of departure, 128
  of elevation, 109, 282
  of fall, 129
Appendix, 275

Balance of shotguns, 187
Ballard breech action, 245
Ballistic coefficient, 77, 127
Ballistics,
  definition of, vii
  exterior, vii, 73
  interior, vii, 1
  interior, numerical, 31
  of shotguns, 187
  pendulum, 40
Ballistic Tables,
  .45-90 Springfield, 284
  .303 British, 309
  .30-40 Krag Jorgensen, 287
  .30-06 Springfield, 290
  Winchester of 1907, 292
  Winchester of 1941, 295
  recoil and penetration, 301
  pistol and revolver cartridges, 302
  recoil of shotguns, 307
  low power weapons, 308
Barometer, 114
Barrel length and velocity, 6
  length of shotguns, 109
  time, 8
  time of shotguns, 199

Bench rest shooting, 169
Blast, muzzle, 71
Brady, James F., 45
Brake, muzzle, 71
Brush shells, 209
Bullet wear, 26
Burrard, Major Gerald, 66

Care of arms and ammunition, 213
Cartridges,
  .22 Long Rifle, 98, 150, 249
  .22 Hornet, 23, 100, 152, 242
  .22 Kilbourn Hornet, 11
  .22-3000, R-2, 23, 100, 112, 152, 248
  .218 Bee, 152
  .219 Zipper, 152
  .22 Savage H.P., 11
  .22 Varminter, 23, 102, 152
  .220 Swift, 23, 102, 152
  .25 Rim Fire, 132
  .25-20 S.S., 11, 12, 13, 153, 245, 249
  .25-20 W.C.F., 25, 112, 153, 246
  .25-35, 11, 12, 13, 153
  .250-3000 Sav., 11, 13, 153, 271
  .257 Roberts, 11, 153, 253
  6.5 m/m Mannlicher, 153
  .270 Win., 23, 105, 153
  7 m/m Mauser, 153
  .30 MI Carbine, 97
  .30-30 W.C.F., 24, 102, 141, 153
  .300 Savage, 153
  .30-40 Krag, 24, 149, 154, 258, 260
  .30-06 U.S., 24, 94, 149, 154, 262, 267, 270
  .300 H & H Magnum, 154
  .303 British, 147, 154
  .32-40, 154, 242, 245
  .33 Pope, 243
  .33 W.C.F., 154, 256
  .348 W.C.F., 102
  .35 W.C.F., 256

Cartridges (*Continued*)
.38 S & W Special, 24
.357 S & W Magnum, 155
.38-55, 154
.38-56, 240
.375 H & H Magnum, 156
.40-70-330, 154
.40-72, 155, 241
.40-82, 240
.45-70, 149, 155, 240, 284
.45-90, 110, 155, 240, 269
.505 Gibbs, 265
.577 Black Powder, 138, 270
Baker Baby, 158
See also Appendix
Chandler, William Astor, 269
Choke of shotguns, 189
Chronograph,
Aberdeen, 48
Le Boulenge, 45
rotary, 44
Smith, 40
Chronology, 273
Cleaning,
arms, 213
bolts, 215
brushes, 215
cloths, 216
exceptions, 221
guards, 215
methods of, 218
patches, 216
precautions, 221
rod, 214
Cross-section paper, 110
Crossman, E. C., 256
Crossman, Mrs. Edward C., 51
Crusher gauge, 33-37
Coefficient of form, 128
Combustion chamber, 10
Compensator, Cutts, 72
Competitive small-bore shooting, 60
Corrosion, 25
Coxe, Wallace H., viii
Cummings, C. S., ix

Danger space, 96
Density of loading, 15
Dram equivalent, 195
Drift, 79-81
Drop of bullet, 79

Energy, 129
Enfield (S.M.L.E.) Rifle, 68
Erosion, 20, 24
in shotguns, 24
Evans, Frank, 243
Extreme Range, 119

Firing point, 159
Fouling, 17
Friction by bullet, 26

Garand rear sight, 91
rifle, zeroing, 108
Gas cutting, 25
Gravity, force of, 73, 77
Grease, rust inhibiting, 217
Groove Diameter, Tables, 278

Handbooks on reloading, 230
Hand loading ammunition, 229
Hatcher, Major General Julian S., viii
Hills, shooting up and down, 116
Hudson, Dr. W. G., 132

Ignition, 2

Johnson, Mrs. Martin, 51
Jump, 19, 50, 55
direction of, 64
in auto-pistol, 71
influence of stock, 62
in revolver, 69
of shotguns, 200

Killing Power, 136
British opinion on, 145
effect of sectional density, 145
effect of shock, 147
effect of velocity, 145
effect of weight and diameter, 145
of black powder cartridges, 137
of expanding bullets, 141
of revolver cartridges, 155
of shotguns, 202
of modern rifles, 139
of sharp pointed bullets, 140
of 45-90 rifle, 269

Laudensack, A. L., 250
Leaded barrels, 222
Le Boulenge Chronograph, 45
Lever action rifles, 252
Lewis, Thomas N., 45
Loading, density of, 15
Lock Energy, 1
Lock Time, 1

Mann, Dr. Franklin W., 45, 84, 163
Mathematical reminders, 276

Mean radius, 176
Metal fouling, 224
Metal fouling solution, 226
Metford, W. E., 65
Metric system, 276
Micrometer sight adjustment, 89
Mil, 276
Minutes of angle, 88, 275

Niedner, A. O., 256
Nutting, Philip, 22

Oiled case pressure gauge, 36
Oils for lubricating and care, 217

Pattern of shotguns, 190, 203
Pendulum, ballistic, 40
Penetration tests, 148
Pistol, automatic, interior ballistics of, 31
Pope, Harry M., 66, 162
Pressure, 9
  determination, 33
  estimation, 38
  gauge, 33-38
    radial, 34
    oiled case, 36
    Piezo, 38
  of shotguns, 193
Primers, chlorate, 222
Primers, strength of, 3, 4
Point blank range, 105
Powder,
  burning of, 4
  fouling, 17
  improvement in, 19
  New du Pont, I.M.R., 18
Powell, E. Baden, 134

Quick, C. L., 45

Rabbeth, J. F., 245
Radial pressure gauge, 34
Ranges, 157
  winter, 159
Recoil, 19, 50
  appreciable, 50
  calculation of, 53
  initial, 54
Records, 157, 182
  cards, 185
  old, 238
Reloading ammunition, 229
Remaining velocity, 128
Rests, 157
  bench, 165
  machine, 161
  Mann "V", 163
  Pope, 162
  Woodworth cradle, 164
Resting the rifle, 57, 258
Revolver, interior ballistics of, 29-31
Resistance of air, 73
Rifled slug loads, 210
Robinson, Merton A., viii
Rules for sight adjustment, 92
Rust, 25

Score book, 183
Sectional density, 128
Shells,—see *shotguns*
Shorkley, Major George, 246
Shotguns,
  ballistic balance, 187
  ballistics of, 187
  barrel length, 199
  barrel time, 199
  comparison of gauges, 211
  choke, 189
  extreme range, 210
  field, trap and skeet loads, 198
  high velocity loads, 196, 198
  killing power, 202
  pattern, 190, 203
  pressure, 193
  standard velocities, 197
  velocity, 195
Shot,
  for shotguns, 201
  concentrators, 209
  extreme range of, 210
  stringing, 208
Shot sizes, tables of, 304
Shoulder of case, 10, 11, 12
Sights, in connection with trajectory, 86
Sighting shots, 60
Single ball loads, 210
Slopes, trajectory on, 116
Smith, J. Bushnell, 40
Solid gilding metal bullets, 264
Spiral, air, 83
Spotting scopes, 161
Storage of arms and ammunition, 213-223
Sulphur cast, 268

Targets, 91, 161
  frames for, 158
  measurement of, 174
  N.R.A., 91

Temperature, 28, 114
Time of flight, 128, 129
Tip of bullet, 83
Trajectory, 74, 85, 86
  determination of, 121
  flatness of, 94
  heights, 92
  numerical determination, 127
  on slopes and hills, 116
  revolver and pistol, 118
  screen tests, 125
  tables,—see Appendix
Trajectory of cartridges,
  .22 Rim Fire, 98
  .22 Hornet, 100
  .22-3000, R-2, 100, 112
  .22 Varminter, 102
  .220 Swift, 102
  .25-20, 112
  .257 Roberts, 253
  .270 Winchester, 102
  .30-M1 Carbine, 97
  .30-30 W.C.F., 102
  .30-06 U.S., 94
  .348 Winchester, 102
  .45-90 Winchester, 110
Twist of rifling, tables, 278

Variations, powder and bullet, 264
Velocity,
  determination of, 33, 39
  instrumental, 47
  muzzle, 47
  remaining, 128
  and barrel length, 6
  of shotguns, 195
Vibration, 19, 50, 55
  of shotguns, 200

Wabble of bullet, 83
Wads, top for shotguns, 209
Walsh, J. H., 65
Wells, Major General Briant H., 139
Western Tool & Copper Works, 15
White, Stewart Edward, 271
Wind,
  deflection, 79, 129
  direction and force, 131
  tables, 133, 134
Windage micrometers, 91
Witsil, W. E., ix
Worn muzzle, 257
Wounding effect, 136

Yaw, 82

Zero of Garand rifle, 108
Zero sight adjustment, 106

Gunsmithing

By Roy F. Dunlap

A 1950 work on gunsmithing—the most complete ever written, containing information on every phase of gunwork from selection of the stock blank on through to the metal engraving and blueing. It is *thorough!*—with not only the "what" and "how" but also the "why." This work was instigated by the publisher and written at his request by Roy Dunlap with a view of replacing Baker's *Modern Gunsmithing*, which was written back in 1927. Everyone who has read Dunlap's manuscript says it is "better'n Baker."

The average user of firearms will find this book to be of value in its technical information on barrels, action bedding, accuracy adjustments and trouble corrections. The shotgun information is exceptionally complete and practical. One can read exactly how the job he wants should be done and how to have the guns fitted properly to himself so that he can get the most out of them.

The targetshooter will be interested in the chapters on modern target rifles, their barreling and chamber work, their special furniture and fittings. Dunlap is a hard-boiled, competent rifleman and his information on rifles of precision is backed by trial, experience, quite a few medals and trophies, and many a head of big game.

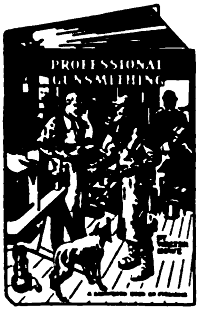
The general gunsmith will gain information he has never been able to find except through trial and error. Individual shotguns, rifles, revolvers and pistols are covered in detail, their weak points mentioned, and instructions given as how to fix them without the use of a fully equipped shop and special, expensive machinery.

For the first time, complete and official cartridge and chamber specification drawings are published, with headspace data and barrel threadings, on modern cartridges from the .22 long rifle to the .375, including the more popular wildcats. All barrel shank and thread data is shown by drawings as well as dimensions. Barrel specifications and rifling information in all calibers is listed and analyzed.

Above all—although complete and thorough—this book is not written over the shooter's head. Written and published with the definite aim of turning out the most possible up-to-date information and instruction under one cover—*Gunsmithing* is the best one-book buy that can be obtained today. Its pages are crammed with instruction and formulae necessary in all phases of the gunsmithing art. Professional, amateur, or just plain shooter—this Dunlap work is by far the best shooting-buy offered at the start of the half-century. It has been four years in the making and will prove a milestone in gun literature equal to Baker's famous work of three decades back.

Gunsmithing is sold under the guarantee that it is better and more applicable today than any other published work on that craft. 800 pages—200 illustrations—36 chapters of the most modern, most complete, best all-around book on gunwork published. Price $7.50

Professional Gunsmithing



By Walter Howe

Gunsmithing methods and textbooks, like everything else, are matters of evolution and change for the better. This is particularly true of the many technical books on gunsmithing now in existence—each in part records or augments the gradual but positive progress of the craft as time goes by.

Here is a recent work written entirely from the professional outlook and devoted mainly to the repair and modification of existing stock weapons. "*Professional Gunsmithing*" approaches the subject from an entirely new angle, supplementing and enhancing all other previous Samworth Books on Firearms treating of this vital matter of gun repair and upkeep. It combines both business and technical phases of gunsmithing, in that matters such as time, ethics, price estimation, how to deal with shooters as customers, and the idea of doing the job exactly as someone else demands and not as the gunsmith himself might want to do it, are given paramount consideration throughout the text.

How to best set up a gunshop and what is more important, how to keep it going on a profitable basis is included in this volume. Subjects such as business set-up and customer relationship are presented in a clear, understandable manner. Several speciality lines which will provide a satisfactory source of revenue are included and the listing of sources of supplies for all gunsmithing materials is the most extensive yet published.

Anyone entering the gunsmithing field, either as a means of livelihood or merely to work on their personal firearms, will find a mass of applicable material herein. The subject of commercial gunsmithing is taken up by Howe in a broad and comprehensive manner, approached from the angle of basic principles and logical reasoning. He tells how to diagnose gun troubles when the weapon is brought in for repair and explains the general reasons and causes for necessity of such repairs. By applying Howe's "approach" to the problem in hand any gunsmith will be enabled to correctly and profitably remedy the fault or repair the defective part.

Walter Howe's instruction is concise and practical because he knows whereof he writes. Specific jobs and types of repair work which have proved to be most frequently brought into the gunshop during his experience as a practicing gunsmith, are treated in detail. The amateur will appreciate this instruction as the advice of a master craftsman; the professional will be impressed with its clarity and practical application to the problems which daily confront him.

"*Professional Gunsmithing*" is today's outstanding textbook for the gunsmithing profession, and is now being used as such in colleges and training schools which include gunsmithing in their curriculum. 520 pages, 120 special drawings, 21 plates. Price $6.00.

Checkering and Carving of Gunstocks

By Monty Kennedy

Gunstock ornamentation has been a subject of compelling personal interest to most owners of firearms for the past five centuries and has ranged from the practice of hammering-in lines and whorls of brass nails on up to the meticulous inlaying of mother-of-pearl and semi-precious stones into the wooden stock. Such decorative tastes have leveled-off in the past 100 years and now are confined mainly to the checkering and carving of the gunstock, with a minimum of inlays.

During the past decade American gunmakers have been hard put to meet the increasing demand for more artistic ornamentation to grips and forearms, yet, at the same time, meet the necessary requirements prescribed by usage in hunting fields and on target ranges.

Checkering and Carving of Gunstocks meets the demand for a treatise covering this art of gunstock ornamentation. It is an extensive and specialized work of 244 text pages and some 300 technical illustrations that covers its subject fully from both utilitarian and decorative standpoints. The author, Monty Kennedy, is a top-flight professional gunstocker with several years of steady work at the checkering cradle to back him up, and he tells herein all he knows.

In addition to the author's comprehensive instruction, this book gives the methods, procedures, tools and patterns of such top-ranking craftsmen as Tom Shelhamer, Leonard Mews, John Hearn, Leighton Baker, Keith Stegall, Hal Hartley, Roy Dunlap and many others. Each describes at length his distinctive checkering methods and illustrates his personal choice of actual patterns.

There are some 75 of these checkering patterns shown—each in full size with basic starting lines located—all ready to be used as a template of sorts for transfer to your own gunstock. Notes and comment as to its application by the beginner accompany each pattern. Patterns range from easy ones to some that will take many, many jobs before experience enough has been acquired to start in on them.

The past few years have seen an increasing demand for carved gunstocks, so to help meet this growing trend we present, in full size, some 40 applicable and highly attractive carving patterns—forearm, grip and buttside—of big game, game bird, animal, and leaf-and-seed designs. Nothing conventional here; these are definite, easily recognizable patterns from nature's storehouse, highly original in conception and done by leading American artists. The beauty and appeal of these splendid patterns must be seen to be appreciated and this feature will set a new milestone in custom decoration by American gunmakers. Accompanying these patterns is the essential basic instruction on carving and suggestions as to the application of these particular designs.

Monty Kennedy's great work will prove of equal value to the experienced gunmaker with years of practical experience to his credit, as well as to the man or boy out in the hills with his first standard grade of gun and a bit concerned about that smooth, unfinished look to its grip and forearm. Either of these extremes will find something in *Checkering and Carving of Gunstocks* that can be applied to the gun-in-hand at the particular moment. **Price $5.25.**